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The Combined Harvester-Thresher in Ohio

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THE COMBINED HARVESTER-THRESHER IN OHIO

ECONOMIC CONSIDERATIONS

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The use of the combined harvester-thresher in Ohio is a very recent development. The idea of harvesting and threshing grain in one operation is not new. There are records in the United States Patent Office of the granting of a patent for a combined harvester-thresher as early as 1828. Several other early attempts to develop the combine were made, but not until 1890 were any manufactured for general distribution. The use of the combined harvester-thresher was for many years confined to the arid and semi-arid regions of the United States, and not until the beginning of the past decade was there any tendency for them to cross the Rocky Mountains. By 1924 a few combines were being tried east of the Mississippi River.

In 1926 there were known to be 3 combines in Ohio, in 1927 the number increased to 40, and by the close of the 1928 harvest season the total number had grown to 94. In 1929 the location of 138 combines was known; in 1930 the manufacturers reported the sale of 37 new machines, bringing the total on record to 175. However, the exact number of combines in the State is not definitely known, but it is probably somewhat larger than the number given above. The rapidity with which the combined harvester-thresher method of harvesting has spread over this country can best be shown by the total number of combines sold in the United States, which in 1923 was 1099; in 1926, 6277; and in 1929, 19,666.[2]

The continually increasing problem of reducing cost of production to meet the changing price levels has been one of the important causes for the increased interest in the combine. The practicability and dependability of the combine with our type of farming and weather conditions have been uppermost in the minds of many of our farmers.

Studies on the various phases of the combined harvester have been carried on jointly by the Agricultural Engineering and the Rural Economics Departments during the years 1928, 1929, and 1930.

[1]Rural Economics Department.
[2]Figures on total sales taken from *The World Wheat Outlook, 1930.* U. S. D. A. Miscellaneous Publication No. 95; p. 29.

USE OF THE COMBINE IN OHIO

LOCATION OF COMBINES

The combines in Ohio in 1930 were almost all located in the level or gently rolling areas in the western half of the State. Only a few combines have been purchased in the eastern section of the State. The operation of combines has been confined to the principal, small grain areas, but more particularly so to the wheat-producing areas of the State. Figures 1 and 2 give the location of the wheat- and oats-producing areas. The combines on which records of location were available were distributed over the State in 1930 as follows:

County	No.	County	No.	County	No.
Allen	6	Franklin	6	Ottawa	4
Ashland	1	Fulton	4	Paulding	4
Ashtabula	1	Gallia	1	Perry	1
Auglaize	1	Greene	2	Pickaway	6
Butler	6	Hancock	4	Preble	1
Champaign	5	Hardin	5	Ross	2
Clark	3	Henry	5	Sandusky	4
Columbiana	1	Huron	2	Seneca	6
Crawford	1	Logan	4	Shelby	1
Darke	3	Lucas	7	Union	11
Defiance	1	Madison	10	Warren	2
Delaware	3	Marion	8	Wayne	1
Erie	2	Miami	2	Williams	1
Fairfield	1	Montgomery	3	Wood	26
Fayette	3	Muskingum	1	Wyandot	4

The information dealing with the cost of operation and other economic phases of the combined harvester was obtained by personal interviews with the owners of combines. Records on 75 combines in 1928 and 78 in 1929 were obtained after the close of the harvest seasons. In 1928 and 1929 records on 90 different combines were obtained, owners of 63 of the machines were interviewed both years, and the remaining 27 only one year. Twenty-nine of the owners interviewed in 1928 had operated their combines in 1927 and were able to contribute information on the 1927 harvest. Following the 1930 harvest, records were obtained from seven men who operated windrow equipment in connection with their combines.

SIZE AND TYPE OF FARMS OPERATED BY OWNERS OF COMBINES

Ownership of the combine up to the present time has been largely among farmers who are operating farms that are considerably above the average in size. The owners of 85 of the combines on which records were secured operated, on the average, 427 acres per machine. The five remaining combines were operated entirely as custom machines and were owned by men who did no farming. Ten of the 90 combines were owned cooperatively, nine machines by two-partner combinations, and one machine by a three-partner

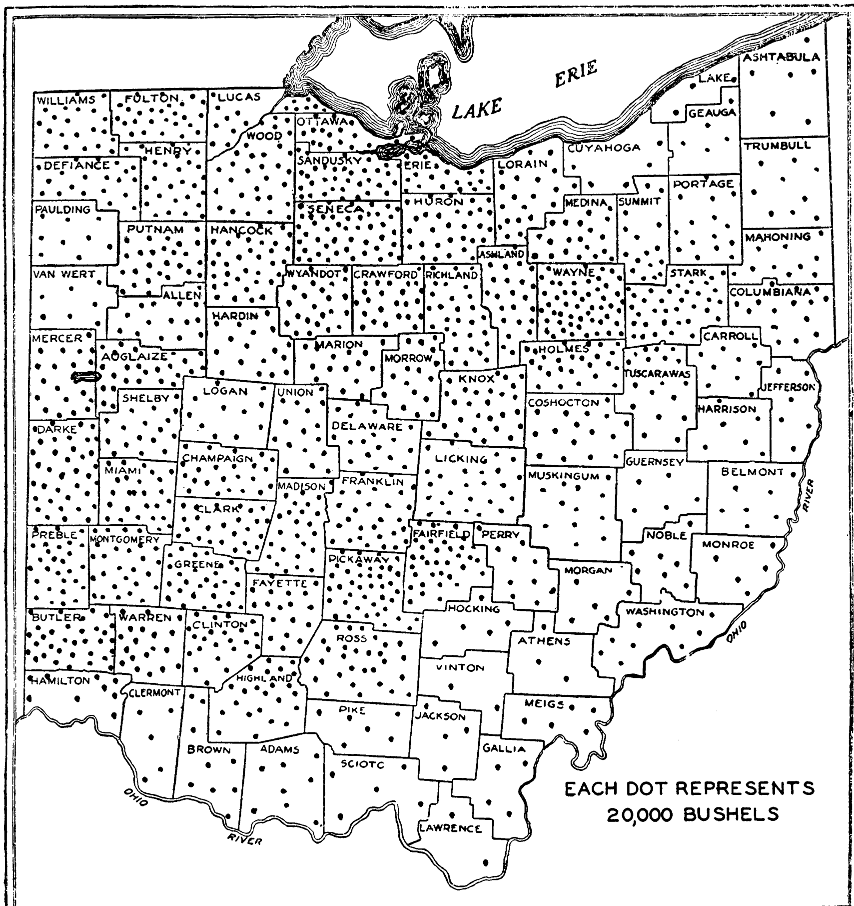


Fig. 1.—Wheat-producing area in Ohio, 1920 to 1929

combination. An average of 213 acres was operated by each of the farmers owning machines cooperatively, and a total of 448 acres was operated for each combine owned cooperatively. The 72 farms on which one or more combines were owned by an individual farmer averaged 442 acres. Sixty-one per cent of all the land operated by owners of combines on which records were obtained was owned by the operator and 39 per cent rented. The average-size farm, according to the 1930 Census of Agriculture for the State, was 98 acres, and less than 3.5 per cent of the total number of farms in the State were over 260 acres.

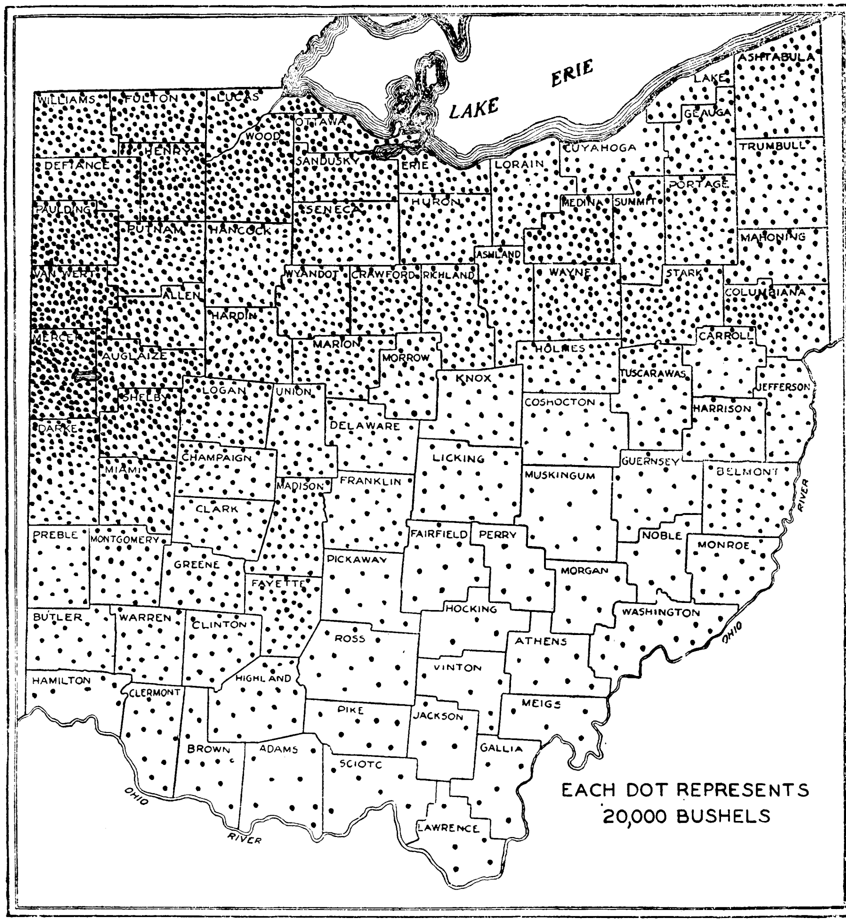


Fig. 2.—Oats-producing area in Ohio, 1920 to 1929

The fact that most of the farmers owning combines in Ohio are located in the small grain growing sections of the State would in itself indicate that grain production is one of the chief enterprises on their farms, if not the chief one. In 1929 the farms operated by the 72[3] farmers who were interviewed averaged 402 acres, 245 of which were in grain crops. One hundred and thirty-seven acres, or a little over one-third, were in small grain.

TABLE 1.—Acres Operated by a Farmer or Group of Farmers Owning One or More Combines

Size of farm operated	Number
Acres	
150 or less	5
151 to 250	16
251 to 350	18
351 to 450	16
451 to 550	10
551 to 750	8
751 and over	9
Custom operators	5
Farms with 2 combines	3
Total	90

Approximately one-third of the farmers interviewed were primarily grain farmers keeping only sufficient livestock to operate the farm and for family needs. One-third of the farmers, in addition to grain production, were feeding hogs and beef cattle. General, dairy, and miscellaneous specialized farms made up the remaining third.

TABLE 2.—Crops Raised per Farm on 72 Farms Owning Combines in 1929

Acres in farm	402
Acres in small grain	137
Corn	108
Wheat	67
Oats	32
Barley	4
Soybeans	26
Miscellaneous crops	8

SIZE AND COST OF COMBINES

Thirteen of the 90 combines included in the study had cutter bars of less than 10 feet in width, 55 were 10-foot-cut, 15 were 12-foot-cut, and 7 were 16-foot-cut machines. All of the 13 combines of less than 10-foot cut were purchased before 1928. Four of the 22 machines with larger than 10-foot cut on which records were obtained were purchased in 1927, 13 in 1928, and 5 in 1929.

[3]Ten of the farmers interviewed in 1929 owned combines in partnership and were unable to report acreages of the various crops raised on their partner's farms. Consequently, only the farm of the reporting partner was included in the figures on crops raised per farm in 1929. Three of the 72 farmers interviewed operated two combines. In addition to the the records secured from the 72 farmers, three records were secured from custom operators.

Seventy-nine of the 90 combines were of the auxiliary motor type and 11 were of the power-take-off type. The power-take-off type machines were all purchased in 1926 and 1927. Thus far the 10-foot-cut machines have been the most popular in Ohio, as indicated by the fact that over 60 per cent of the combines included in the study were of the 10-foot size.

TABLE 3.—Size and Price of Combines Studied

Width of cut	Number of combines	Average price
		Dollars
Less than 10-foot	13	1300
10-foot	55	1475
12-foot	15	1965
16-foot	7	2300

The original cost of the combines in operation in Ohio varied widely, ranging from $1000 to $2700. The price ranged from an average of $1300 for machines of less than 10-foot cut to $2300 for machines of 16-foot cut. The price not only varied with the width of cut but also among the different manufacturers for the same size machine. In the group of combine owners included in the study, nine different makes of combines were represented.

ACRES HARVESTED ANNUALLY

Two hundred and three acres were harvested, on the average, in 1929 by each combine on which a record was obtained, 192 acres per combine in 1928, and the combines that were used both in 1927 and 1928 harvested, in 1927, 185 acres per combine. The smallest acreage of grain harvested in 1928 by any of the combines was 35 and the largest 630. In 1929 the smallest acreage harvested was 30 and the largest 725.[4]

TABLE 4.—Acres Harvested Annually by Different Width Cut Combines

Width cut	1927		1928		1929	
	Number	Acres per combine	Number	Acres per combine	Number	Acres per combine
Less than 10-foot	11	162	13	129	9	180
10-foot	15	201	45	203	50	195
12-foot	2	113	11	204	12	220
16-foot	1	344	6	222	5	289
Average	29	185	75	192	76*	203

*The two combines on which records were obtained in 1929 that were used in 1928 but not in 1929 were not included.

[4]Two combines owned by men interviewed both in 1928 and 1929 were not operated in 1929.

The Ohio operator has had a wide variety of uses for the combine because of the diversified type of farming which makes available a longer season for combining and a larger acreage to be combined. The machines combining 300 or more acres in 1929 harvested on the average four different kinds of crops; whereas the machines combining less than 100 acres harvested only two kinds of crops.

TABLE 5.—Acres of Crops Harvested by Combines Studied

Crop	Acres harvested		
	1927	1928	1929
Wheat	2,329	2,224	6,861
Oats	1,360	6,162	3,265
Barley	418	3,143	758
Soybeans	690	1,737	3,233
Buckwheat	49	353	454
Rye	....	61	205
Timothy	47	....	330
Red clover	112	116	344
Sweet clover	351	136	....
Miscellaneous	13	439†	....
Total acres	5,369	14,371	15,450
Number of combines	29	75	76*
Acres per combine	185	192	203‡

*The two combines on which records were obtained in 1929 that were used in 1928 but not in 1929 were not included.

†Mixed grains.

‡The average yields per acre of the crops harvested with a combine in 1929 were as follows: wheat 23 bu.; oats 36 bu.; barley 21 bu.; soybeans 18 bu.; rye 13 bu.; buckwheat 10 bu.; red clover 1 bu.; and timothy 5 bu.

In addition to the advantages obtained by our diversified farming, the annual use of the combine has been greatly increased by the custom work done for neighboring farmers. Thirty-eight per cent of the acreage harvested by the combines studied in 1929 was custom work; in 1928, 29 per cent was custom work, and in 1927, 21 per cent. Twelve of the 29 combines in 1927 did some custom work, 46 of the 75 in 1928, and 54 of the 76 in 1929. The importance of the custom work on the annual use is shown by the fact that in 1929 the machines doing some custom work combined more than twice as many acres per machine as did those doing no custom work.

RATE OF HARVEST

The acres harvested per hour by the combine varied from less than 0.5 of an acre to over 3.5 acres per hour, with an average of 1.7 acres in 1928. In 1929 the rate ranged from 1 to 4 acres per hour and averaged 2.0. From the mechanical standpoint the width of cut of the combine has been and will be an important factor in the amount harvested per hour. However, in the short period of the combine's existence in Ohio other factors have had at least as great an influence on the rate of harvest as the width of cut. The experience and ability of the operator in handling the combine has had much to do with the rate and success. The rate of harvest has, also, been influenced by the weather, condition of the grain, length of straw taken into the combine, and amount of green plant growth present. The increase in the average rate in 1929 over 1928 was undoubtedly due to several factors, but experience of the operator and better crop conditions played an important part.

TABLE 6.—The Acres Harvested per Hour by Combines of Various Widths in 1928 and 1929

Crop	Less than 10-ft. cut		10-ft. cut		12-ft. cut		16-ft. cut	
	1928	1929	1928	1929	1928	1929	1928	1929
Wheat	1.48	1.59	2.08	1.98	1.91	2.51	2.09	3.24
Oats	1.23	1.47	1.68	1.75	1.47	2.19	2.00	2.90
Barley	1.18	1.40	1.96	1.80	2.38	1.97	1.55	3.10
Soybeans	1.43	1.33	1.53	1.73	2.03	2.35	2.83	2.88
Average	1.27	1.46	1.79	1.84	1.67	2.34	2.02	3.03

Those factors influencing the rate of harvest also influenced the number of hours each day that the combines were operated. Although the most common starting time was about 10 A. M. and the stopping time about 6 P. M., there were many days when conditions were such that only a few hours of harvesting were possible, others when the combine could not be operated, and still others when it was possible to work longer than 8 hours. Both in 1928 and 1929 there was considerable variation among individual operators and in different sections of the State as to the length of working day for the combine. The average for the State in 1929 was 7.7 hours per day.

Crop	Hours per day	
	1928	1929
Wheat	8.2	8.25
Oats	8.0	7.8
Barley	7.8	7.9
Soybeans	6.8	6.9

The slight variation in the length of working day for the combining of wheat, oats, and barley was largely due to the difference in the nature of the straw. The shorter period of daylight at the season of the year in which the soybeans were harvested was the most important cause for the shorter working day in soybeans. On the basis of the average length of combine day and the number of acres per hour, the average daily accomplishment for combines of different width for the more important kinds of crops harvested is given in Table 7.

TABLE 7.—Acres Harvested per Day by Combines of Various Widths in 1928 and 1929

Crop	Less than 10-ft. cut		10-ft. cut		12-ft. cut		16-ft. cut	
	1928	1929	1928	1929	1928	1929	1928	1929
Wheat	12.1	13.2	17.1	16.3	15.7	20.7	17.1	26.8
Oats	9.8	11.5	13.4	13.7	11.8	17.1	16.0	22.6
Barley	9.2	11.1	15.3	14.2	18.6	15.6	12.1	24.5
Soybeans	9.7	9.2	10.4	11.9	13.8	16.2	19.2	19.9

COST OF HARVESTING BY THE COMBINE METHOD

FACTORS OF COST INVOLVED IN HARVESTING

The cost of man labor, tractor power, fuel, lubricants, and repairs or operating costs incurred while combining were only a part of the actual cost of harvesting a crop. The depreciation of the combine, the interest on the money invested, and taxes must also be considered as a part of the harvesting cost and must be added to the operating costs to obtain the total cost of combining. The total cost per acre for combining was influenced by several factors, and, consequently, there has been considerable variation in costs among individual operators in the State. Operating costs, or the costs other than overhead, were affected by the rate of combining, the number of hours per day the combine was operated, the size of the crew, the kind of crop, the amount of fuel and lubricants used, the repairs, and other minor items. The total annual overhead costs (depreciation, interest, and taxes) were affected primarily by the original cost and estimated life of the combine; the per acre overhead costs were affected by the acres harvested annually.

The cost of combining as presented in this analysis includes all the labor and expenses incurred in harvesting a crop up to the point where the threshed grain was delivered at the grain spout. The costs involved in moving the threshed grain from the machine to the bin or elevator, although a part of the harvest expense, were not included in the cost of combining. The wide variation in farm conditions, such as the type of conveyance used for hauling the grain, the distance that the grain was hauled, the method of storage, and the facilities for unloading, introduced items and differences in costs for which the combine was neither directly nor indirectly responsible. These differences existed regardless of the methods of harvesting. In 1928, 60 per cent of the operators employed one man to dispose of the grain after it was threshed, 33 per cent two men, and 7 per cent used three or more men. Both wagons and trucks were used to haul the grain away from the machine, and often where one man took care of the grain two or more wagons or a wagon and truck were brought into service for moving the grain.

A crew of two men, one man on the tractor and one on the combine, was the most common for the operation of the combine, exclusive of the men hauling the grain. A few machines, mostly of the power-take-off drive type, were operated by one man. Occasionally, three men were used when combining conditions were unfavorable. For the sake of uniformity and comparison a uniform charge of 30 cents per hour for man labor, the common wage at that time, was used.

With but two exceptions all of the combines included in the study were drawn by tractors; in the two cases four horses were used for all or part of the season. The size of tractor used depended on the size and type of combine and also on the size of tractor on the farm when the combine was purchased. The combines of the power-take-off type were all drawn by tractors of the three-plow size. Three-plow tractors or larger were used by all, except one, of the operators of 16-foot combines and by two-thirds of the owners of 12-foot-cut machines, the remaining third using tractors of the two-plow size. The 10-foot-cut and smaller combines were practically all drawn by tractors of the two-plow class. A rate of 75 cents per hour for the two-plow tractors and of $1.00 per hour for the three-plow tractors was used to cover all tractor costs except fuel and oil. In determining the cost of operating the combines of 10-foot cut or less, the 75-cent rate was used in all cases except for the machines of the power-take-off type. The operating costs of the power-take-off machines, the 12-foot- and the 16-foot-cut combines were all computed on the basis of the three-plow tractor rate ($1.00 per hour). Horse work, where used, was charged at the rate of 12 cents per hour.

The cost of fuel and lubricants used by the tractor and auxiliary motor on the combine was determined on the basis of the amount reported used by each operator and at the price delivered at the farm. The price of gasoline used was the price at the farm, less the 4-cent gasoline tax.

The average yearly repair cost for the life time of the combine is not known because the combine has not been used a sufficient number of years as yet in Ohio. Undoubtedly, the repair bill will increase as the age of the machine increases. So far, the repairs have been a minor item in most cases. The manufacturer usually replaced the broken parts which were defective the first season after the combine was purchased; thus, but little check on the costs was possible. During the second and third year of use, operators reported repair costs ranging from little or nothing to $15 or $20 in most cases, although a few operators had costs as high as $100 or more. In computing the operating cost of combining, repairs were included as reported by the individual operator.

Depreciation, interest, and taxes (the important items of overhead cost) were more difficult to measure than the operating costs. The life of the combine has a direct bearing on overhead costs, but the combine has not been used long enough in Ohio to determine, by actual use, the length of life. Moreover, the combine is in the process of development and may decrease in value as much from obsolescence as from actual wear. The operators' estimates ranged from 5 to 20 years, but the majority placed the life of the combine at 10 years. The estimated length of life apparently had little relation to the annual use, and under actual conditions the length of life will probably depend more upon the ability of the operator and the care that the machine receives than upon the annual use. Undoubtedly, machines with large annual usage will wear out more rapidly than machines used on small acreages, but no logical method of measuring this difference for the combine has been developed. Taking the estimate of the majority of the combine operators as a basis, 10 years were used as the estimated life of the combine in the determination of the annual depreciation charge. Interest and tax costs were charged at the rate of 6 per cent on the first cost of the combine for the first year of use and for the second and succeeding years at the same rate on the value of the combine remaining after the previous year's depreciation had been deducted.

OPERATING COST

The operating costs for combining an acre of grain by different width cut machines in 1929 ranged from $1.32 per acre for the combines with less than 10-foot cut to 78 cents per acre for the combines with a 16-foot cut. The average operating cost for the 10-foot combine was $1.08 per acre. The increased rate of harvesting by the larger combines was largely responsible for their lower operating costs. Operating costs for machines of the same size varied with the kind of crop harvested. With few exceptions, the operating cost for harvesting wheat was the lowest, primarily due to the slightly higher rate of combining and a somewhat longer working day, Table 8.

TABLE 8.—The Average Operating Cost per Acre in 1929

Width cut	Average	Wheat	Oats	Barley	Soybeans
	Dol.	*Dol.*	*Dol.*	*Dol.*	*Dol.*
Less than 10-foot	1.32	1.23	1.45	1.40	1.59
10-foot	1.08	.98	1.10	.98	1.28
12-foot	1.04	.92	1.10	1.33	1.10
16-foot	.78	.70	.81	.76	.87

OVERHEAD COST

The overhead cost has been considered as an item of fixed annual cost and on this basis the greater the annual acreage harvested the smaller is the overhead cost per acre. The total annual overhead cost per combine for the different width machines is given in Table 9. The overhead cost on the 16-foot-cut machines averaged 62 per cent more than the overhead on the 10-foot combines in 1929. To offset the higher overhead cost it would have been necessary for the 16-foot machines to have harvested approximately 120 acres more than the average acreage combined by the 10-foot machines. In actuality, in 1929 the 16-foot combines harvested, on the average, only 94 acres more than the 10-foot machines.

TABLE 9.—Average Annual Overhead Cost, 1929

Width cut	Number	Total per combine	Acres harvested per combine	Cost per acre
		Dol.		*Dol.*
Less than 10-foot	9	209.00	180	1.16
10-foot	50	221.00	195	1.14
12-foot	12	311.00	220	1.42
16-foot	5	358.00	289	1.24

TOTAL COST

The total cost, or the operating plus overhead costs, makes up the actual expense of combining an acre of grain. The average total cost per acre in 1929 was $2.02 for five, 16-foot-cut combines; $2.48 for the twelve, 12-foot combines; $2.22 for the fifty, 10-foot combines; and $2.48 for the nine machines with less than 10-foot cut. The 10-foot-cut machines harvested the most economically in 1928; while in 1929 the 16-foot machines had the lowest total cost per acre.

The total cost per acre was fairly uniform for the different crops, with a tendency for the cost to be somewhat lower in 1929 than in 1928. The decrease was largely due to a reduction in overhead costs by greater use rather than a lowering in operating expense. The labor requirement per acre was lowest for wheat and highest for soybeans; consequently, the total operating cost per acre was higher on soybeans than on the other small grains. However, the per acre overhead costs were lower on soybeans than on wheat, oats, or barley. This was due primarily to the fact that the combines that were used to harvest soybeans harvested a larger annual acreage than those which were confined to one or two small grains. The individual items of expense entering into the total cost of harvesting an acre of grain with a 10-foot, auxiliary motor driven combine are given in Table 10.

TABLE 10.—The Average Total Cost per Acre for Harvesting Grain With a 10-foot-cut, Auxiliary Motor Driven Combine, 1928-1929

	Wheat		Oats		Barley		Soybeans	
	1928	1929	1928	1929	1928	1929	1928	1929
Acres combined	891	3,689	2,787	1,433	1,384	311	693	1,967
Hours per acre	0.48	0.49	0.59	0.56	0.51	0.56	0.65	0.60
Cost per acre, Dollars:								
Man labor	0.29	0.29	0.35	0.33	0.30	0.32	0.39	0.36
Tractor power	0.36	0.37	0.44	0.42	0.38	0.42	0.49	0.45
Fuel and oil for tractor	0.15	0.16	0.18	0.17	0.16	0.15	0.20	0.22
Fuel and oil for combine	0.12	0.11	0.14	0.13	0.13	0.11	0.16	0.16
Repairs on combine	0.03	0.07	0.03	0.09	0.04	0.07	0.06	0.08
Miscellaneous costs	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Total operating cost	0.98	1.03	1.17	1.17	1.04	1.10	1.33	1.30
Depreciation, interest, and tax	1.34	1.28	1.48	1.15	1.38	1.03	.96	.94
Total cost	2.32	2.31	2.65	2.32	2.42	2.13	2.29	2.24

In 1929, the average total cost for the entire season per 10-foot-cut combine was $438.00, and the total amount harvested was 195 acres per combine, making the average cost per acre $2.26. In 1928 the total cost per machine was $465.00, the acreage harvested 201, and the average cost per acre $2.31. The 10-foot-cut combines, in 1929, that harvested less than 100 acres had a total cost per acre of $5.26, as compared with eight machines that harvested 300 or more acres at a cost of $1.63 per acre. The effect of the acreage harvested annually on the total cost per season and per acre is given in Table 11. The total cost in the 1929 season for the group harvesting less than 100 acres was 77 per cent overhead cost, as compared with 36 per cent for the group harvesting 300 or more acres.

Wheat, oats, barley, and soybeans were the only crops in Ohio that were combined in sufficient quantity to justify any detailed cost analysis; however, combining costs were determined on clover, timothy, rye, and buckwheat. Because of the small acreages of these crops combined, no classification according to the size of combine was made. The operating cost per acre in 1929 was as follows:

Clover	344 acres	$1.14 per acre
Timothy	350 acres	1.02 per acre
Rye	205 acres	1.26 per acre
Buckwheat	454 acres	1.02 per acre

COST OF HARVESTING BY THE WINDROW-COMBINE METHOD

Records were obtained from seven farmers who operated windrow equipment in connection with their combines in 1930. The windrower is very similar to the headers used in the West and was devised to overcome some of the difficulties encountered by the combine in the middle West.

Up to the present time a very small percentage of the grain combined in Ohio has been harvested by first using a windrower and then picking it up from the swath. In 1930 the total acreage windrowed by the seven operators interviewed was 2119, of which 13 per cent was wheat, 60 per cent oats, 23 per cent barley, and 4 per cent sweet clover. One of the seven owners operated two windrowers making a total of eight on which records were secured. Two hundred and sixty-five acres were windrowed per machine in 1930. The average original cost per windrower was $333.00 and for the pick-up attachment $142.00, making a total cost of $475.00 per outfit, in addition to the original cost of the regular combine. Seven of the windrowers were 12-foot-cut machines and one was a 16-foot-cut. All of the machines were operated by one man each and drawn by a tractor, the majority of which were of the two-plow rating. The length of working day was 10 hours, and the average daily accomplishment was 40 acres.

The cost of operating a windrower, including man labor, tractor power, fuel, oil, and repairs, averaged 33 cents per acre in 1930. The overhead cost of the windrower and pick-up attachment, like the combine, depends on the length of life. Because of newness of the machine the operators hesitated even to place an

TABLE 11.—Total Annual Cost per 10-foot-cut Combine, 1928-1929

Items of cost	Acres of grain harvested annually											
	Less than 100		100 to 149		150 to 199		200 to 249		250 to 299		300 and over	
	1928	1929	1928	1929	1928	1929	1928	1929	1928	1929	1928	1929
	Dol.	*Dol.*	*Dol.*	*Dol.*	*Dol.*	*Dol.*	*Dol.*	*Dol.*	*Dol.*	*Dol.*	*Dol.*	*Dol.*
Operating cost:												
Man labor	28.05	19.32	44.40	43.33	46.83	55.35	86.69	80.40	89.63	87.30	122.85	109.61
Tractor power	30.78	24.15	55.45	54.16	66.60	66.19	105.68	100.50	120.91	109.12	163.80	137.00
Fuel for combine	12.35	7.65	20.11	20.15	21.64	20.07	37.43	31.72	36.55	30.70	57.33	45.08
Fuel for tractor	12.33	10.95	26.80	22.17	24.97	28.45	44.30	43.07	53.43	42.10	73.71	66.73
Repairs on combine	0.91	2.50	0.16	10.46	2.49	6.50	19.37	17.77	18.68	12.43	40.95	39.60
Miscellaneous expense	2.78	1.62	2.76	3.84	4.50	5.07	8.80	6.93	7.03	8.04	15.56	11.43
Total operating cost	87.20	66.19	149.68	154.11	167.03	181.63	302.27	280.39	327.23	290.69	474.20	409.45
Total overhead cost	225.50	220.27	242.92	246.57	229.68	218.11	222.36	199.26	226.36	232.55	215.82	224.02
Total operating and overhead cost	312.70	286.46	392.60	400.68	396.71	399.74	524.63	479.65	553.59	522.24	690.02	633.47
Average cost per acre	4.19	5.26	3.16	3.10	2.40	2.34	2.41	2.04	1.99	1.92	1.70	1.63

estimate on the length of life. On the basis of the assumption that their life will be the same as the estimated life of the combine (10 years), the overhead cost[5] averaged 29 cents per acre, making the total cost of windrowing 62 cents per acre.

The average rate of combining the windrowed grain was 24.4 acres per day, and the average length of day was 9.6 hours in 1930. Four of the eight combines used in combining the windrowed grain were 10-foot-cut machines and four were 12-foot-cut. As was previously mentioned, all of the windrowers were 12-foot-cut machines except one, the result being that all of the eight combines used to harvest the windrowed grain picked up 12-foot windrows, except one machine which followed a 16-foot windrower. Because of this uniformity there was practically no difference in the rate between the 10- and 12-foot-cut machines when combining the windrowed grain. The average operating cost for combining the 2119 acres of windrowed grain was 90 cents per acre and the overhead cost was 69 cents, making a total cost of $1.59 per acre for the combining. The total cost per acre for the windrowing and combining was $2.21.

In view of the fact that overhead costs depend almost entirely upon the acreage harvested annually and that there was considerable variation in the annual use of the combine in the State, comparisons between the cost of straight combining and combining by the windrow-combine method are more comparable when operating, rather than total, costs are used.

The operating cost for harvesting an acre of grain by the windrow-combine method in 1930 was $1.23 per acre, as compared with $1.05 for straight combining with the 10-foot-cut and $1.01 for the 12-foot-cut machines in 1929.[6] By this comparison, the operating costs for the windrow-combine method were 17 per cent greater than straight combining with the 10-foot machines and 22 per cent more than with the 12-foot-cut. It must be recognized that the cost figures for the windrow-combine method are based on a small sample and for only one year. To draw any definite conclusions on costs a longer period and larger sample would be required.

OLD AND NEW METHODS OF HARVESTING COMPARED

To compare the combine method with the binder and stationary-thresher method, information was collected in 1928 on the binder and stationary thresher at the same time and from the same

[5]Computed by the same method used in determining the overhead on the combine.

[6]The average operating cost for straight combining is based on the same crops (wheat, oats, and barley) as were harvested by the windrow-combine method in 1930.

farmers that used combines. A majority of the binders owned by the farmers interviewed in the study were 7- and 8-foot size and of the horse-drawn type, although a large number of the farmers were using tractors to pull their binders. A small number of the larger farms were using special 10-foot-cut tractor binders previous to the purchase of the combine. On farms using tractor-drawn binders the rate of harvest was 18 to 20 acres per day and somewhat less for horse-drawn machines. The average and most common size of crew used in cutting and shocking was four to five men.

The per bushel charge for threshing varied from one community to the next and in the different sections of the State. The average per bushel charge for wheat was 6.2 cents; for barley, 5.6 cents; and 3.8 cents for oats. The average rate of threshing for wheat, barley, and oats was 4 acres per hour. To make the data comparable with the combine, the labor and expense involved in threshing with the stationary separator were included up to the point where the threshed grain was delivered at the grain spout. The average size crew needed to get the grain to the machine and threshed was 11 to 13 men and 6 to 8 teams.

TABLE 12.—Harvest Cost per Acre for Grain Cut With Tractor-drawn Binder and Threshed With Grain Separator, 1928

	Wheat		Barley		Oats	
	Quantity per acre	Cost per acre	Quantity per acre	Cost per acre	Quantity per acre	Cost per acre
Man labor, cutting and shocking*	2.24 hr.	$0.67	2.55 hr.	$0.77	2.33 hr.	$0.70
Tractor for cutting†	.52 hr.	.52	.54 hr.	.54	.45 hr.	.45
Twine‡	2.1 lb.	.26	2.1 lb.	.26	2.7 lb.	.32
Depreciation, interest, and tax on binder	....	.25	....	.25	....	.25
Man labor, threshing*	2.57 hr.	.77	3.23 hr.	.97	3.10 hr.	.93
Horse work, threshing§	2.69 hr.	.32	3.44 hr.	.41	3.33 hr.	.40
Threshing bill**	....	1.12	....	1.40	....	1.56
Total cost	....	$3.91	....	$4.60	....	$4.61

*Labor charge for cutting grain and threshing was at the rate of 30 cents per hour.
†Tractor power cutting grain charged at $1.00 per hour, all costs included.
‡Twine charged at 12 cents per pound.
§Horse work charged at 12 cents per hour.
**Average rate of charge for threshing in 1928, as reported by farmers interviewed: wheat, 6.2¢; barley, 5.6¢; and oats, 3.8¢.

The depreciation on the binder was figured on the basis of a 12-year life[7]; and to make comparison possible with the combine it was assumed that both binder and combine were new at the same time. Interest and taxes were charged at 6 per cent on the first cost the first year and on the depreciated value the second and succeeding years. The depreciation, interest, and tax costs of the sta-

[7]Average life of binder based on information obtained from farm-cost studies in Ohio.

tionary thresher were included in the per bushel threshing charge. The amount of twine used was based on information obtained from farm-cost studies in Ohio.

Approximately one man hour per acre was required to harvest an acre of grain with a 10-foot combine, and 5 man hours were required to harvest an acre of grain with a tractor-drawn binder and stationary thresher. Two men were as large a crew as was needed to accomplish the task with the combine; whereas by the binder-thresher method a crew of 4 or 5 men was needed to cut and shock the grain when tractor-drawn binders were used, and 11 to 13 to thresh it. In terms of machine hours per acre (actual time, combine or binder and thresher were operated), the binder-thresher method in 1928 required 50 per cent more time per acre than the combine method. The total cost per acre for the binder-thresher method was, by this comparison, 78 per cent greater, on the average, in 1928 than the combine method of harvesting grain.

TABLE 13.—The Combine and the Binder-thresher Method of Harvesting Compared, 1928*

	Wheat	Barley	Oats
Cost per acre, dollars:			
Combine method	2.32	2.42	2.65
Binder-thresher method	3.91	4.60	4.61
Labor per acre, hours:			
Combine method			
Man labor	.96	.99	1.15
Tractor	.48	.51	.59
Binder-thresher method			
Man labor	4.81	5.78	5.43
Tractor	.52	.54	.45
Horse work	2.69	3.44	3.33

*The 10-foot combine was used in the comparison.

The outstanding advantage of the combine method of harvesting over the binder and stationary-thresher method is its ability to reduce the amount of man labor required; however, a part of the saving in labor is offset by the higher machine cost. In periods of high wages the saving in man labor by the use of machinery materially reduces harvest cost. But in periods of low wages and high-priced machinery the advantage of reducing labor by replacing it with a high machine cost is greatly lessened. Consideration must also be given to the fact that a large part of the farm labor in this State does not require an actual cash outlay; and, if it were to be partially replaced in harvesting with a combine, the actual saving would depend upon what other use could be made of the labor saved.

CUSTOM WORK WITH THE COMBINE

The use of the combine harvester for custom work materially increased during the period of the study. As was previously mentioned in the discussion on annual use, custom work increased from 21 per cent of the total acreage harvested in 1927 to 38 per cent in 1929. Three of the combines included in the study in 1929 were used entirely as custom machines, but the majority of the custom combining so far has been done in addition to the harvesting on the operator's farm. The most common rates of charge for custom work in 1928 and 1929 were $3.00 to $4.00 per acre, although a few operators charged as low as $1.50 and one as high as $6.00. There were three operators who charged by the bushel and one operator set a flat rate of $2.00 per acre, plus 10 cents per bushel. There was practically no difference in the custom rate for the different crops combined.

In areas where the combines have been operating successfully farmers have gained confidence in the combine, as indicated by the demand for custom work. The most noticeable increase in demand for custom work was in the soybean harvest, where thus far the combine has demonstrated its superiority in most cases over other methods of harvest.

THE STRAW PROBLEM

The importance of straw for bedding and to a less extent for feed varies widely among farmers. To the dairy and poultry farmer a plenteous supply of straw for bedding is very important and to a somewhat less extent to the beef cattle feeder because coarser materials can be substituted. The grain farmer with the combine has practically no straw problem; in fact, the spreading of the straw in the field has eliminated the problem of disposing of the old straw stacks. A third of the farmers included in the study were primarily grain farmers, and, as the amount of livestock kept was small, very little material was needed for bedding. An equal number of combine owners, in addition to grain production, were feeding beef cattle and hogs. With these men the bedding problem was more important, and coarse bedding, such as corn fodder, was used partially to replace the loss of straw. The remaining third of the combine owners were operating general and specialized dairy and poultry farms with a definite bedding problem, a problem that could be partly met by the use of coarse bedding but met most satisfactorily with straw.

The straw problem was handled in various ways by the farmers interviewed. On farms where the combines were new, straw from old stacks and fodder generally supplied the needs and in a few cases where the combine was 2 years old the same method was used. Most of the farms used fodder, both shredded and unshredded, for bedding—some depending on it entirely, others only for part. When no old straw was to be had and straw was needed, some farmers bought straw, but the total amount purchased was small; others gathered up straw after combining and still others harvested and threshed some of their grain by the old method to secure the straw. A few farmers used a combination of these methods to secure straw when large amounts were needed. In 1929, nineteen farmers raked up some straw after the combine. The yield of straw after it was combined was usually small unless the grain was combined close to the ground and rather often was of poorer quality by the time it had been combined, loaded from the windrow onto a wagon, and then baled or stored loose in the barn. The methods of handling the straw are discussed in the latter part of the bulletin.

THE ADAPTABILITY OF THE COMBINED HARVESTER-THRESHER TO OHIO CONDITIONS

The combine has been used for many years in the West under conditions quite different from those in Ohio. The fact that the combine was first developed under conditions different from those in Ohio does not necessarily mean, however, that it is not adapted to Ohio, because changes can be and have been made. Ohio in some respects lends itself readily to the combine; in other respects it presents some important difficulties. The topography of the important grain areas in the State is favorable to the operations of the combine. The number of different crops raised that can be harvested with a combine makes possible a longer combine season and, consequently, the possibility of a larger acreage to harvest annually. The weather conditions during the period of the study (1927-1930) have probably been as favorable for the combine as for the binder-thresher method and may continue to be in the future. This, however, will require a longer period of time to demonstrate than the 4 years that the combine has been in use in the State. During the period of this study, the combines on which records were obtained experienced some difficulties because of the weather, probably due as much to the inexperience of the operator as to the weather. In a season of heavy rains and soft wet ground, the weight of the combine is a limiting factor both in its inability to operate, and, if able to operate, in its effect on the ground. The binder-thresher method is not free from the same fault, but with that method it is less pronounced. The majority of Ohio farms are not sufficiently well drained to avoid soft ground completely during extremely wet periods.

In seasons favorable for weed growth, Ohio is probably as much troubled by weeds as the other states in the middle west. By either method of harvesting, weedy grain causes trouble; however, with the combine, unless the grain is windrowed, the green growth tends to increase the moisture content of the grain to the extent that the keeping quality of the grain is endangered. The tendency for some of the grain to ripen a little unevenly some years presents to the combine about the same problem as weedy grain.

The size and type of farm in Ohio seems to be one of the most difficult problems for the combine to meet. The tendency has been more toward greater diversification in the specialized grain areas than toward larger grain farms. The diversification has been largely accomplished by the addition of dairy and poultry to the farm business, both of which were enterprises that increased the demand for straw. The size of farm in Ohio is a decided handicap, as compared with some of the other states in which the combine has spread rapidly as a method of harvesting. The average size farm in Ohio was 98 acres in 1930, as compared with 143 in Illinois and 283 in Kansas. Approximately three-fourths of the combines in Ohio on which records were obtained were operated on farms of 260 acres and over. In Ohio in 1930, 3.5 per cent of the farms were 260 acres or over, as compared with 11 per cent in Illinois and 32 per cent in Kansas. On the average small farm the limited acreage of grain to be harvested, the small fields, narrow lanes, and gates, limited storage space for farm implements, and the need for straw are all factors that tend to check the spread of the combine. The limited funds available on the average Ohio farm for as large a capital investment as the combine, regardless of its economies in harvesting, will continue to be a point in favor of the binder-thresher method.

Probably the best proof of the adaptability of the combine to Ohio conditions, particularly to the weather and crop conditions, must be the actual demonstration of the combine's success in the State. The stamp of approval will naturally rest with the farmers and the operators of the combine. When asked if the combine was adapted to Ohio conditions and if they believed it would be a success, most of the combine owners interviewed believed that the method of harvesting would be a success and were very well satisfied with the combine. The owners were asked to state the advantages and disadvantages of the combine. The following are some of the more common statements given:

Advantages.—(1) Lowers harvesting costs. (2) Reduces harvest labor. (3) Reduces length of harvest season. (4) Makes one independent of exchange labor. (5) Picks up down grain better than binder. (6) For the grain farmer, spreads the straw. (7) Reduces cost and number of harvest meals.

Disadvantages.—(1) Large investment. (2) Loss of straw. (3) Difficulty in handling green material. (4) Uncertainty of weather.

ENGINEERING CONSIDERATIONS

E. A. SILVER[8]

CONSTRUCTION OF COMBINE

The present combine harvester-thresher much resembles a stationary grain thresher with the addition of a platform or header to cut the grain and elevate it to the cylinder. Inasmuch as a stationary thresher must be kept perfectly level at all times, adverse criticism was raised when combines first appeared that this machine would be very wasteful of grain because of the impossibility of keeping it level. This feature, however, is not an outstanding disadvantage in the use of the combine except when operating on side hills of 4 per cent grade or over.

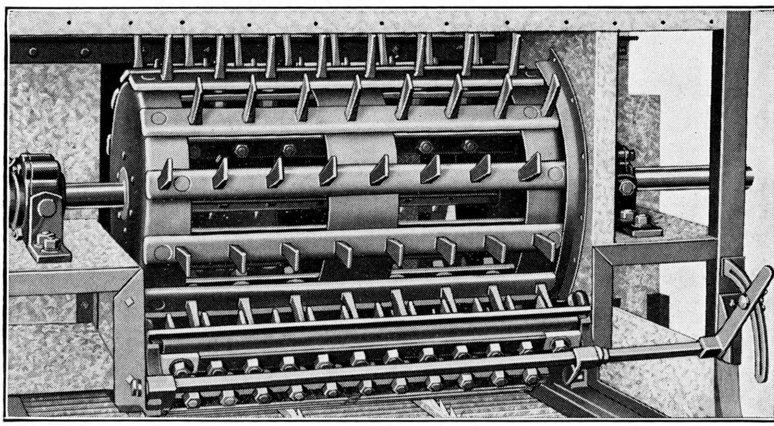


Fig. 3.—Spike-tooth cylinder used on combines in Ohio
Courtesy of Avery Power and Machinery Co.

TYPES OF CYLINDERS

Two general types of cylinders are used on combines: the spike- or peg-tooth and the bar or rasp cylinders. Other types are being developed but are not as yet in general use. The spike-tooth cylinder has been used in this country quite extensively on stationary grain separators.

The bar-type cylinder was introduced into the United States about the time that combines were developed. The spike-tooth cylinder has always been very satisfactory for threshing sheaf grain. Due to the fact that the breaking up of the straw and green

[8]Department of Agricultural Engineering.

material in the crop by the cylinder overloads the separating mechanism, some claim that the bar type of cylinder is somewhat more adaptable for combine operation. Concaves are used with both types of cylinders—the spike-tooth cylinder having a spike-tooth concave and the bar cylinder having a series of rubbing bars set cross-wise in the machine. Either type of concave is adjustable.

SEPARATING EQUIPMENT

Inasmuch as the separation of the grain from the straw and chaff is more difficult in combine threshing than in stationary threshing, the separation units should be of ample capacity to function properly under all crop conditions.

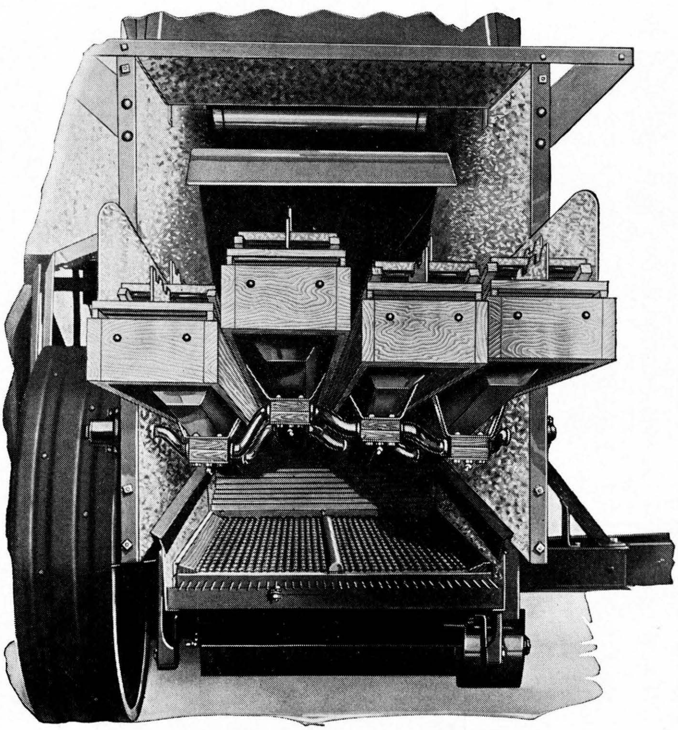
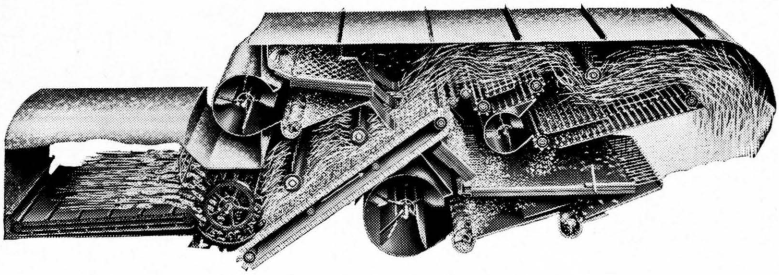


Fig. 4.—Types of straw racks commonly used on combines
A. Rotary rack

Courtesy of Massey-Harris Co.



B. **Raddle or apron rack**

Courtesy of Caterpillar Tractor Co.

C. **Vibrating rack**

Courtesy of Avery Power and Machinery Co.

The three principal types of straw racks are: the rotary, the vibrating, and the raddle or apron type of rack. Also, modifications of these types are sometimes used. As the grain, chaff, and short pieces of straw drop through the straw rack, the grain is caught on the grain pan and delivered to the cleaning shoe which contains one or more screens. These screens may be of the adjustable or non-adjustable types. The grain makes its way down through the screens where a blast of air blows the chaff out over the rear of the machine. As the grain proceeds downward it falls to the shoe auger where it is then elevated to the recleaner or to the bin.

RECLEANERS

In order to clean the grain better and to relieve the cleaning shoe, some makes of combines have recleaners. This device is similar in construction to a fanning mill. It is usually mounted above and at the front of the straw rack. The grain, as it is elevated from the lower grain pan, passes through the sieves in the recleaner and is then augered or elevated to the grain bin. The short pieces of straw or other material are carried over the screens and dropped to the straw rack below.

Various devices are used to screen the weed seed from the grain. One device which has appeared recently and is very effective if the material is fairly dry is the rotary weed screen or "squirrel cage".

The rotary weed screen is cylindrical in shape and is generally located above the grain tank. The grain enters at one end, and, as it passes along, the weed seed sifts through the revolving screen and falls into a spout below where it is sacked. The cleaned grain is released at the end of the screen and is dropped into the bin. Another type of weed screen is located in the clean-grain elevator. Along the bottom of this elevator is a plate perforated with small holes. As the grain is drawn over this plate the weed seed falls through and is collected in a sack.

POWER REQUIREMENTS

Practically all combines now built are of the individual motor-driven type, to be pulled either by horses or tractor. The power-take-off type was not satisfactory because it was impossible to decrease the rate of travel without decreasing the operating speed of the combine. The rate of travel should be dependent upon the volume of unthreshed material entering the cylinder. It is important that the speed of the threshing cylinder be kept as nearly constant as possible. The tractor operator, therefore, should observe at all times the rate at which the grain is entering the cylinder; hence, a tractor with ample power to pull the combine should always be used. This is especially true if the combine is operating on grades, in soft field conditions, or if the crop conditions are weedy, or where an uneven stand exists.

CARE OF COMBINE

In order to prevent loss of time during the harvest season a combine should receive a thorough inspection either before or after the harvest season, preferably the latter. At that time the machine can be inspected thoroughly for wear and breakages. In addition, the machine should be cleaned thoroughly and oiled. The canvases and belts should be removed and stored in a dry place. Metal parts, such as chains, guards, etc., which have been more or less polished by wear should receive a heavy coating of grease or heavy oil. Wood parts should receive similar treatment either with paint or some other wood preservative. All foreign material, such as straw, weeds, etc., should be removed from the machine. If these precautions are taken, much time can be saved when harvesting commences the following year.

Due to the size of the combine, most farmers lack adequate storage facilities. By removing the platform or header, the grain elevator, and on some the grain bin, the machine can be housed in fairly small space. If these parts are removed from the machine they should never be placed on the ground, but should be placed level on blocks to eliminate warping and at some distance from the ground to prevent the absorption of moisture.

Previous to harvest time the combine should be reassembled and "run in". In addition, it is advisable to give the machine another thorough inspection to determine if any parts will be in need of immediate repair and to make any adjustments on bearings and other parts. If the machine be a new one it should be "run in" for some length of time to be sure that the bearings do not heat. Oil and grease should be used rather generously during this period, especially on the faster moving parts. It is well to consult the instruction book, before starting a new machine, for oiling and greasing recommendations.

While a machine is in operation in the field it should be greased frequently, with particular attention to the faster moving parts on which grease or oil is not readily retained. A thorough, systematic greasing should be done in the morning.

After a day's use the machine should be run to empty it of all grain, the grain bin emptied, and canvases removed and placed inside the combine. If it is not desirable to remove the canvases, they should be loosened and covered with a tarpaulin to protect them from rain or moisture. If the above suggestions are followed, much time will be saved during the harvest season, and the life of the machine will be greatly prolonged.

OPERATION OF COMBINE

To get the best results from the use of the combine, the following practices should be noted and followed as closely as possible:

1. Practice clean farming.
2. Be sure grain is ripe before harvesting; moisture content should be 14 per cent or under.
3. Understand the machine thoroughly and keep it in perfect adjustment at all times.
4. Do not *overload* the combine.
    (a) Regulate the rate of travel to the capacity of the machine.
    (b) Cut just low enough for the cutter bar to get under the heads of grain.

Combine harvesting consists of four rather distinct operations: Cutting, threshing, separating, and cleaning. A large loss of grain and time may result if proper attention is not given to adjustments of the above operations.

CUTTING

Unless the straw is to be saved for feed or for bedding purposes, or the crop is badly lodged, the height of cutting should be medium. It has been found that the grain loss back of the cutter bar is extremely heavy when cutting a high stubble, due to the cutter bar not getting under all heads of grain. It has also been found that the thresher cylinder will do a cleaner job of threshing if the heads of the grain retain part of the stems rather than when the heads are cut off short from the stems. The stems offer somewhat of a retarding action, permitting a more effective stripping or rubbing process. Again, heads of grain with short stems do not feed evenly into the cylinder but string along on the platform canvas where part of them fall to the ground.

Although sometimes necessary, cutting a low stubble is not desirable. The cutter-bar loss will be lessened, but the separation losses will be greater. (See grain losses, Page 37).

Reel adjustment has a great deal to do with even feeding to the cylinder. The reel on most combines is adjustable both in the horizontal and vertical planes. For grain which is more or less tangled and leaning away from the cutter bar the reel should be low and forward. For erect, standing grain the best position is a short distance ahead of the knife and low enough to permit the slats, or "bats", to strike the straw just below the heads of grain. A difference of opinion exists with reference to the number of slats on the reel. Therefore, some machines are equipped with eight and some with six slats. The spiders on some machines are designed for either six or eight slats. For light, short grain, eight slats are preferable. Winding at the outer end of the reel sometimes becomes troublesome under weedy conditions. A band of light sheet iron about 12 inches wide encircling the outer end of the slats will help to solve this difficulty. The reel should never be run any faster than necessary to prevent shattering of the grain before it gets to the carrier on the platform.

THRESHING

The cylinder, regardless of type, will always do a more efficient job of shelling if the grain is fed evenly and steadily so that the speed of the cylinder will be close to its rated R. P. M. The speed of the cylinder should never run much over the rated R. P. M. as the higher speeds have a tendency to break up the material finely, thereby overloading the cleaning shoe. If the cylinder be underspeeded the racks and shoe will not function properly because of a corresponding reduction of speed.

An established rule in stationary-threshing practices is to use as few concaves as possible to get all grain out of the heads. This rule is also applicable to combine threshing and should be adhered to at all times. Another rule which applies to stationary threshing is to set the concaves close. This rule does not always hold true, however, as Figure 5 will indicate:

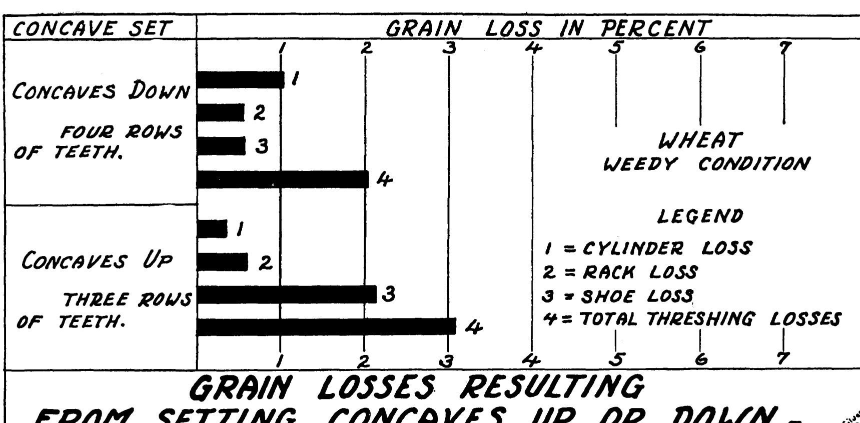


Fig. 5

It will be observed under weedy conditions, therefore, that the separation loss is greater when the concaves are fully set up than when lowered to the maximum. More effective shelling is done when the concaves are fully set up. This applies to the spike-tooth cylinder only, as no comparisons were made on the bar, or rasp, cylinder.

Inasmuch as separation has been found to be one of the heaviest sources of grain loss, every effort should be put forth to relieve the separation units as much as possible, even at the sacrifice of leaving a few kernels in the heads.

SEPARATING

In order to obtain good separation, the racks and shoe should receive close observation and accurate adjustment. In many cases the shoe has been found to be greatly overloaded, and in order to relieve this overloaded condition a number of operators adjust the blinds on the fan so that a heavy blast from this unit will keep the screen clean at all times. This is probably one of the worst remedies for this trouble, because the grain losses are likely to be extremely high.

Sometimes it may be possible to relieve this overloaded condition greatly by following closely the suggestions mentioned under cutting and threshing.

Probably the best method of procedure in trying to eliminate an overloaded shoe is (1) to use a medium blast and (2) to adjust the screens in the shoe (if adjustable) so that a maximum amount of grain passes through and very little is carried over the rear of the screen. If this does not relieve the trouble, cylinder operation and equipment should be inspected. If changes in adjustment have been made on the cylinder or concave equipment it will then be necessary to inspect the shoe again and probably make another adjustment on the chaffer or cleaning sieve. If the trouble is not yet relieved, the rate of travel will have to be reduced, or a longer stubble cut so that less material passes through the machine per unit of time.

The amount of tailings is generally greater on combine harvesting than it is on stationary threshing from the shock or stack. However, in either case the amount of tailings should be as small as possible, as this is generally indicative of good threshing.

CLEANING

Not all combines are equipped with recleaners; however, it has been found that, for Ohio conditions generally, a recleaner is a valuable attachment. Due to uneven ripening of the crop and to some extent to weed growth or other green material, the cleaning shoe is generally taxed to its full capacity. Therefore, some small pieces of green material pass on into the clean grain which affect the keeping or storing qualities. With the aid of a recleaner most of this foreign material is removed. A recleaner, however, even under extreme conditions should never be expected to do the work which was intended for the cleaning shoe.

Operation of the recleaner should be examined at frequent intervals. In the morning when the straw is still somewhat damp and tough it may be necessary to open the sieves slightly (if adjustable) and then close them when the grain is dryer. The air blast will probably require a similar adjustment. Never overload the recleaner by opening the screen or screens in the shoe. If the combine is not equipped with a recleaner, all adjustments must be made on the lower cleaning shoe if a better job of cleaning is desired.

COMBINING ON SIDE HILLS

Most of the combines in Ohio are located in the small grain areas which are more or less nearly level. However, there are a few owners of combines located in the southern and eastern sections of Ohio which are very hilly. Under these conditions the prairie-type combine does not function very satisfactorily because the grain settles to the low side of the machine making it impossible to do a thorough job of separation and cleaning. Figure 6 gives the results of a study on hillside combining.

Side-hill combining does not affect the operation of the cylinder or straw racks to any great extent. The efficiency of the cleaning shoe, however, is lowered greatly. This is due to the material having settled to one side of the screen or screens, reducing the screening area which naturally lowers the quality of the work done. In position A, Figure 6, the shoe loss is much greater than the shoe loss in Position B. This is because in Position B the cutter bar or header is down hill. A combine of the type used has a tendency to deposit the grain at the far side (left side) of the feeder housing. As the grain is carried through by the cylinder it naturally travels down hill and is distributed over more screen area than when the combine is operating in Position A. The grain loss is not excessive until approximately a 4 per cent grade is reached.

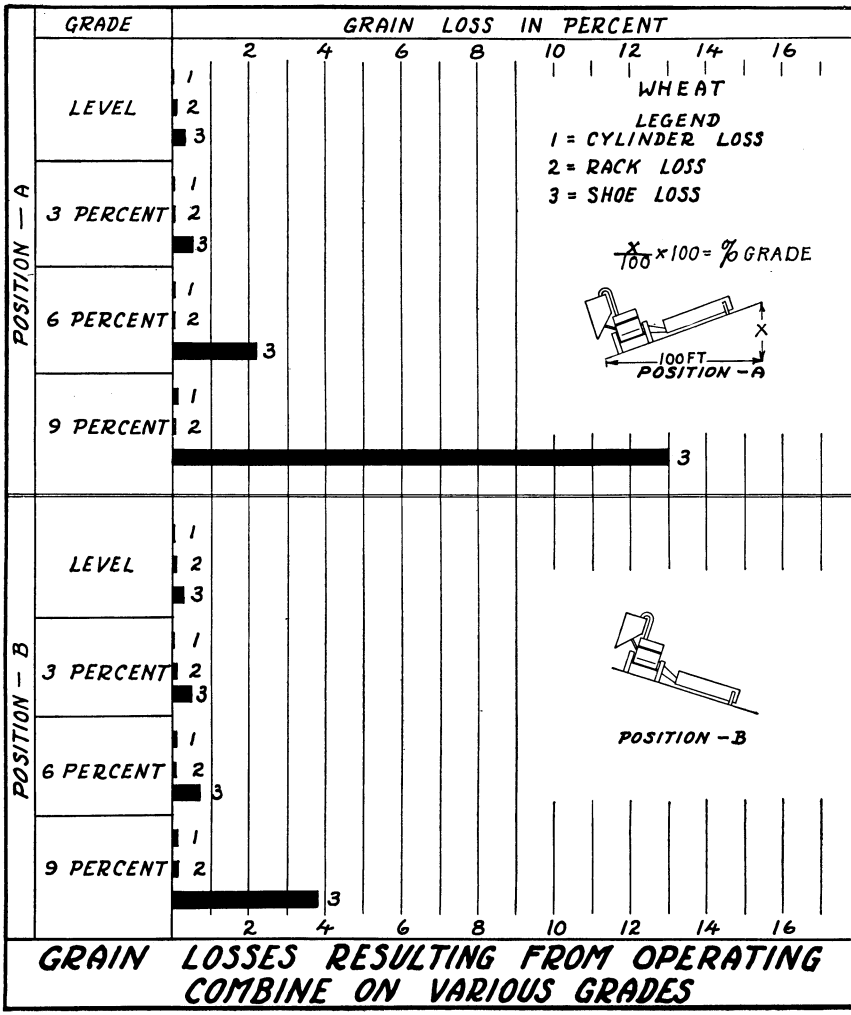


Fig. 6

STRAIGHT OR DIRECT COMBINING

If weather conditions are favorable, straight or direct combining is very satisfactory for wheat and soybeans. Other crops, such as oats, barley, or clover, can also be harvested satisfactorily provided that they have ripened evenly, are free from weeds and second growth, and that the harvesting season be favorable from a weather standpoint. Under bad conditions, it has been found that less risks are taken if the latter crops be windrowed.

For straight combining the grain should be dead ripe. The moisture content of grain should never be above 14 per cent. If the crop is weedy or contains second growth, it should be below this figure. The moisture content of the grain in the combine bin will be higher than that of the uncut grain, due to the liberation of moisture from the green material as it passes through the machine. See Figure 7.

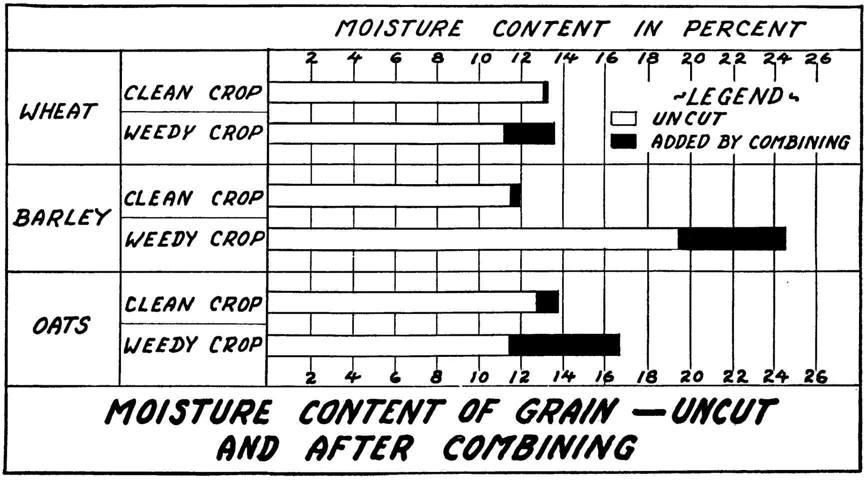


Fig. 7

In addition, the threshed grain will not be perfectly free from weed seed which, when present in the grain stage, will injure the keeping qualities of the grain. If the grain is to receive some drying process or an additional cleaning operation, this factor is not of so much importance.

A thick, heavy crop which has a tendency to lodge is not as detrimental to straight combining as a thin, standing crop. A thick, lodged crop usually does not contain the weed growth that is found in a thin crop. A combine will pick up and thresh lodged grain very satisfactorily and with very little loss if the operators of the combine and tractor show skill in handling the outfits. To prevent excessive grain losses and high moisture content of grain, a combine should not be started too early in the morning or operated to a late hour in the evening. Damp grain can very easily be detected by the slugging effect on the cylinder. Uncut grain which has received a heavy rain should also be allowed a reasonable length of time to dry out. Even, by inspection, if the crop has all appearances of being dry, it may have a high moisture content since fully ripened grain has a tendency to take moisture up through the stem for a considerable period after a rain.

WINDROW SYSTEM OF COMBINING

In Ohio abnormal seasons sometimes occur, causing uneven ripening of the crop, inducing weed growth, and sometimes shortening the length of the harvest season. To overcome these hazards the windrow system of harvesting has been adopted with considerable success. The crop is placed in windrows by means of a windrowing device.

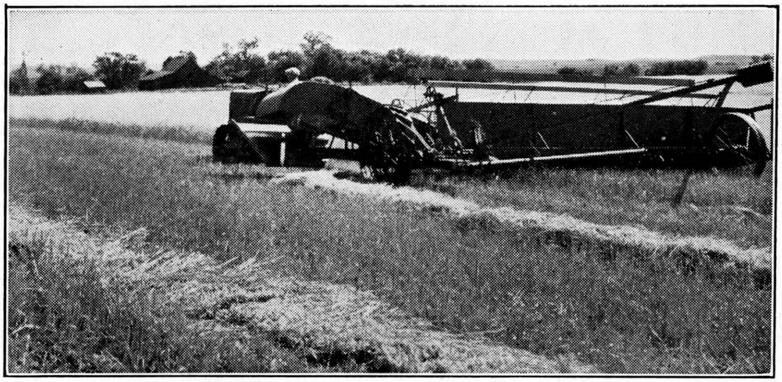


Fig. 8.—Windrowing allows the grain and green material to dry before threshing

Courtesy of Caterpillar Tractor Co.

This device may be a separate unit or it may be the header of the combine mounted on a frame for windrowing purposes. The crop is allowed to dry in the windrows until fit for threshing, then it is picked up by means of a "pick-up" attachment fastened to the cutter bar of the combine, or operated as a separate unit and fastened to the combine.

Probably the two greatest advantages of the windrow method over straight combining are: (1) it permits the curing of weeds and green material before threshing and (2) extends the harvesting period. The green material which is found in most crops, and particularly in oats and barley, is allowed to dry out before threshing. This results in higher quality grain. The combine does more effective work and the grain losses are reduced. The straw, if it is to be saved for feed, is also of higher quality. A windrower can also be operated even if the crop be slightly damp, which permits operation at an earlier hour in the morning and to a later hour in the evening than if straight combining is practiced. The windrow system requires an extra investment. The costs of operating may run from 50 to 60 cents more per acre than by straight combining. However, this extra expenditure is offset by harvesting a larger portion of the crop.

GRAIN LOSSES

STRAIGHT COMBINING

Grain loss is greatly influenced by two general factors; operation and adjustment of the combine and the condition of the crop. The operation and adjustment were discussed in a previous paragraph. The importance of a few simple adjustments is proven by the results given in Table 14.

SOURCES OF GRAIN LOSS

There are four rather distinct sources of grain losses in straight combining: Cutter-bar, cylinder, rack, and shoe. The cutter-bar loss is that grain which does not get upon the platform canvas to be conveyed into the machine and is lost on the ground. This may be grain which is down and missed entirely by the cutter bar, as well as heads which drop to the ground after being cut off. The cylinder loss is that grain which is unshelled by the cylinder; the rack loss is that grain which is shelled by the cylinder but is not separated from the straw; and the shoe loss is the grain which is shelled by the cylinder and is separated from the straw but is carried over the rear of the shoe.

METHOD OF DETERMINING GRAIN LOSSES

To determine these losses, a canvas was trailed behind to catch everything that came over the rear of the machine. The straw was separated from the chaff and loose grain and then rethreshed by a small separator. The test was generally of 30 seconds' duration. In order to get the total amount of grain threshed, the grain was caught in a measure from the clean grain elevator during the 30-second period. Having the total weight of grain threshed and the losses secured from each operation, the percentage loss was easily calculated. The cutter-bar loss was secured by picking up all heads and loose grain on definite areas behind the cutter bar. No effort was made on the straight combining tests to separate the threshed grain losses into rack and shoe losses.

TABLE 14.—Grain Losses—Combine Harvester-Thresher

Test No.	Crop	Method of combining	Height of Crop In.	Height of Stubble In.	Yield per acre Bu.	Grain loss in per cent: Cylinder	Grain loss in per cent: Separation	Grain loss in per cent: Cutter-bar	Grain loss in per cent: Pick-up	Grain loss in per cent: Total	Condition of crop	Moisture content of threshed grain	Adjustments made or recommended on retests
1	Wheat	Direct	40	18	14.86	2.12	1.12	4.62	....	7.72	Clean crop, standing up well.	12.8	....
1-A	Wheat	Direct	36	14	16.20	.34	.52	4.96	....	5.78	Clean crop, standing up well.	11.8	Cut down wind ⅓. Raised concaves up slightly. Incd. cyl. spd. 125 R. P. M.
2	Wheat	Direct	38	20	18.70	.19	.93	10.84	....	11.75	Slightly straw broken.	14.4	Cut down fan blast.
3	Wheat	Direct	42	22	20.78	.15	.38	3.31	....	3.83	Good standing grain.	10.6	....
3-A	Wheat	Direct	42	22	24.06	.08	.31	2.86	....	3.23	Good standing grain.	10.6	Increased cylinder speed.
4	Wheat	Direct	42	18	34.76	.47	.26	5.24	....	5.93	Slightly weedy, straw broken.	13.6	....
5	Wheat	Direct	42	16	14.63	6.67	2.59	16.25	....	24.03	Slightly weedy, straw broken.	14.2	....
5-A	Wheat	Direct	42	16	15.67	1.15	3.96	14.90	....	19.27	Slightly weedy, straw broken.	14.0	(1) Concaves set up slightly; (2) cyl. speed increased to 1110 R. P. M.; (3) tail board part up; (4) lower riddle raised.
6	Wheat	Direct	40	16	15.94	.88	6.61	6.91	....	13.88	Good standing grain.	14.8	Cyl. spd. 820 R. P. M.
6-A	Wheat	Direct	40	16	26.14	.16	.62	4.20	....	4.94	Good standing grain.	14.8	Increased cyl. speed to 1020 R. P. M.
7	Wheat	Direct	44	21	21.44	2.34	.98	6.54	....	9.63	Dry and standing, ground wet.	13.4	Cyl. spd. 960 R. P. M.
7-A	Wheat	Direct	44	21	35.00	.02	.75	3.93	....	5.64	Dry and standing, ground wet.	12.0	Increased cylinder speed to 1010 R. P. M.
7-B	Wheat	Direct	44	21	29.50	.91	.86	3.29	....	5.01	Dry and standing.	11.6	Fan blast reduced and tail-board raised 2 in. after preceding test.
8	Wheat	Direct	48	24	27.03	2.22	1.39	2.45	....	5.98	Straw badly broken.	10.4	....
8-A	Wheat	Direct	48	24	36.74	1.34	1.34	1.10	....	3.75	Straw badly broken.	10.2	Rate of travel reduced.
9	Wheat	Direct	45	20	12.93	1.63	1.96	13.63	....	16.73	Standing up well.	12.4	....
10	Spring Wheat	Direct	28	16	9.49	2.53	4.66	6.52	....	13.25	Very weedy, but standing.	13.4	....
11	Barley	Direct	33	15	15.30	2.09	7.91	3.47	....	13.13	Weedy, straw broken, second growth.	24.2	....
12	Barley	Direct	30	12	29.28	.80	1.91	4.81	....	7.42	Very dry.	11.6	....
13	Oats	Direct	24	8	48.23	.71	4.41	4.48	....	9.37	Badly straw broken, very weedy, mostly sweet clover and milkweed.	14.6	Doing very poor job of cleaning.
14	Oats	Direct	....	....	18.03	1.11	4.71	18.29	....	23.05	Down and tangled, weedy, oats dead ripe.	14.6	....
15	Oats	Direct	30	8	33.50	1.27	1.37	12.31	....	14.63	Badly straw broken and weedy.	16.4	....
16	Oats	Windrow pick-up	40	18	34.15	1.28	1.65	1.21	.81	4.95	Excellent condition.	8.6	....

Note: Tests A or B indicate retests.

The results of grain losses were obtained in a year unfavorable for straight combining. In general, weed growth was heavy, which resulted in low harvesting efficiency. It was necessary to cut high to eliminate the weeds; therefore the cutter-bar losses were generally higher than any of the other sources of loss. In practically every case where it was found that the cylinder speed of the combine was below normal, the threshing or cylinder losses were high. This is shown clearly by the reduction in losses when the speed of the cylinder was raised. In no case was cracking of grain in evidence. The rate of travel was reduced in many instances, due to the condition of the crops.

WINDROW METHOD

The objectives of this work were to secure comparative grain losses and the rate of drying of windrows on various lengths of stubble and in different crops. The rate of drying was also compared with uncut and shocked grain. The work was done along one side of the field to permit of as nearly uniform conditions as possible. The windrower was operated at various heights to establish windrows on stubble from 6 to 18 inches in height. Shocks of grain were set up immediately upon the commencement of windrowing, and likewise a portion of the crop was left uncut.

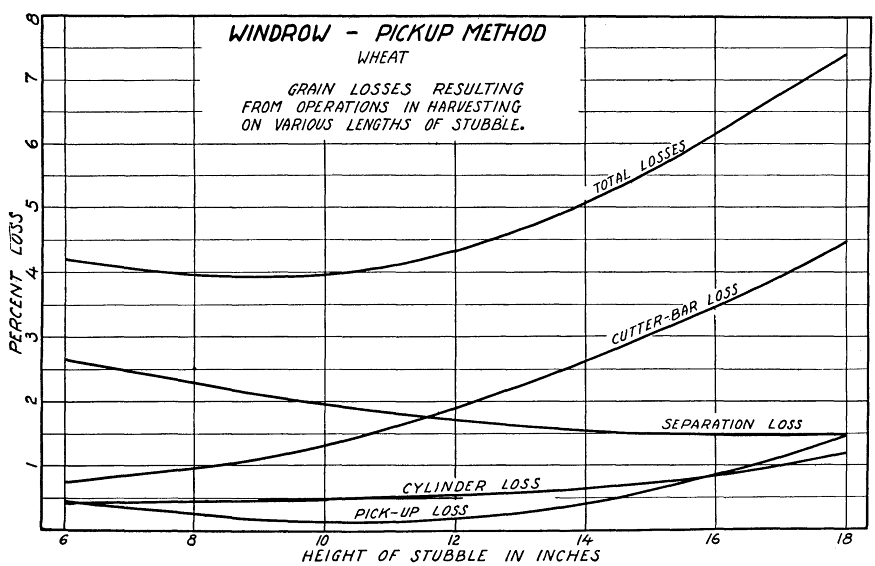
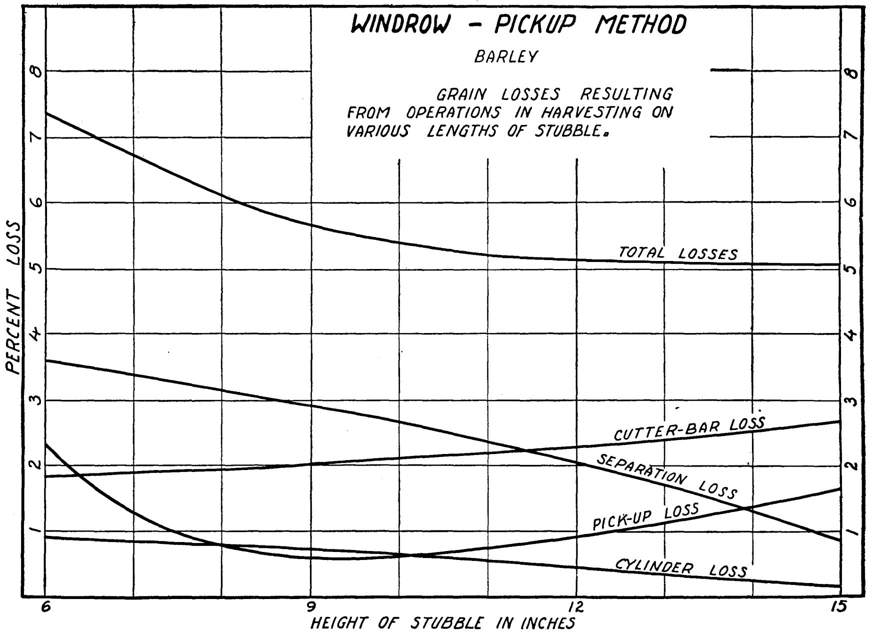
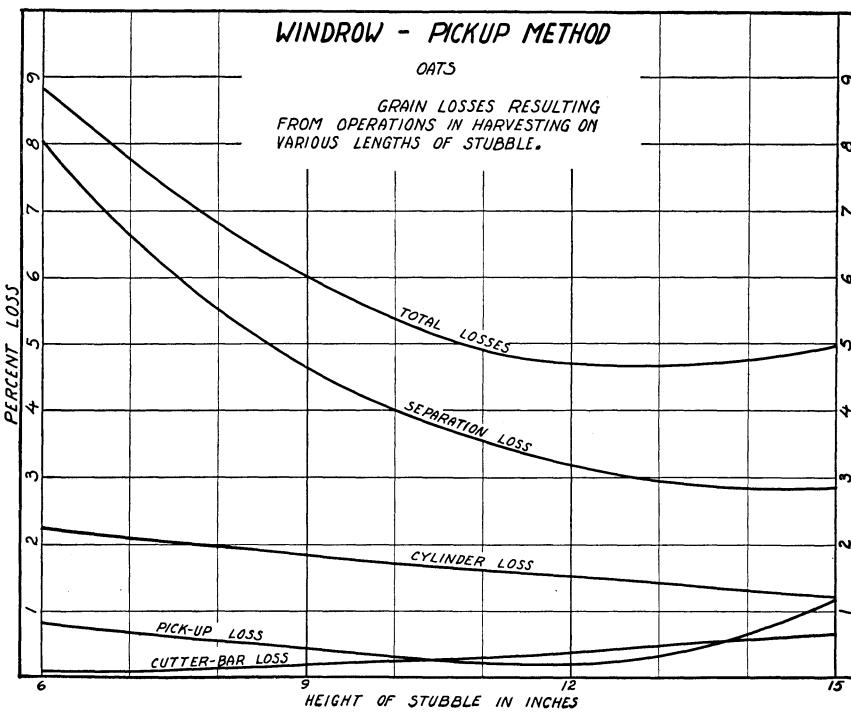


Fig. 9.—A.


WINDROW - PICKUP METHOD
BARLEY
GRAIN LOSSES RESULTING FROM OPERATIONS IN HARVESTING ON VARIOUS LENGTHS OF STUBBLE.
PERCENT LOSS
TOTAL LOSSES
CUTTER-BAR LOSS
SEPARATION LOSS
PICK-UP LOSS
CYLINDER LOSS
HEIGHT OF STUBBLE IN INCHES

B.


WINDROW - PICKUP METHOD
OATS
GRAIN LOSSES RESULTING FROM OPERATIONS IN HARVESTING ON VARIOUS LENGTHS OF STUBBLE.
PERCENT LOSS
TOTAL LOSSES
SEPARATION LOSS
CYLINDER LOSS
PICK-UP LOSS
CUTTER-BAR LOSS
HEIGHT OF STUBBLE IN INCHES

C.

The wheat crop was very light, thin on the ground, and was slightly straw-broken and weedy. This crop was harvested with a 12-foot windrower and threshed with a 10-foot combine of the power-take-off type, travelling at the average rate of 3.3 miles per hour. The grain was not overly ripe but was in a condition similar to that when a binder would usually be started. The average height of crop was 38 inches.

The oats and barley crops were harvested with a 16-foot windrower and threshed with 12-foot combine travelling at the average rate of 2½ miles per hour. The barley was a heavy crop, standing up well, and fully matured. It contained a heavy growth of sweet clover. The oats crop was heavy, a little weedy, evenly ripened, and standing up well. The average height of the oats crop was 36 inches and of the barley 35 inches.

By observing Figure 9 C, it can be seen that the separation loss is the heaviest of all operations. Since the capacity of the combine was smaller in comparison to the size of the windrower used, this would naturally be expected. This combination of sizes is not to be recommended. The separation loss is much less on a 15-inch stubble than it is on the shorter stubble for the reason that the separation units are not overloaded. The separation loss on the wheat crop was less than on the other crops because of the thin stand. The next highest loss is the cutter-bar loss. In the oats crop, however, it was exceeded by the cylinder loss. Oats, generally, if not too ripe and of average height, can be windrowed with very little loss of grain. The swath, as it is cut and conveyed by the canvas, holds together nicely so that very few heads of grain fall to the ground. As would again be expected, the grain loss becomes greater with the longer stubble because of an increasing number of heads of grain slipping by under the knife bar. Cutter-bar losses resulting from a thin stand are extremely heavy when cutting a high stubble, as the curve on wheat will indicate.

The cylinder loss was not high when compared with some of the others. From a 6-inch to a 14- or 15-inch stubble the cylinder loss decreases. Over the 15-inch stubble the losses become slightly greater. This is largely due to the result of a thin, tangled windrow which cannot be fed evenly, heads first, to the cylinder.

The pick-up losses were secured by picking up by hand all heads of grain which were missed by the pick-up device in 25 feet of windrow. This loss was then figured on an acre basis. From all indications the pick-up leaves very little grain in the field if operating at the most desirable length of stubble. The most effective work was done on stubble from 8 inches to 12 inches long. Either below or above these lengths heavier losses occurred. If the windrow is close to the ground the pick-up fingers do not get under it properly and small bunches of grain are left. On the other hand, if the stubble is too long the windrow is open and loosely put together. The stubble is flexible and will not support the windrow properly. The result is that the heads of the grain will drop to the ground and be missed by the pick-up fingers.

The total losses run from 4 to 5 per cent at the lowest point on the curves; this was accomplished at approximately a 12-inch stubble for the heavy crops of barley and oats and at approximately a 9-inch stubble for the thin and straw-broken crop of wheat. As a general thing, the total losses mount considerably with the short stubble. However, with a thin crop the grain losses are not severe on a short stubble. In conclusion, therefore, to reduce grain losses to the least possible amount, cut a 12-inch stubble, or $\frac{1}{3}$ the total length of the straw, for average to heavy crops, and a 9-inch stubble, or approximately $\frac{1}{4}$ the total length of the straw, for thin straw-broken crops.

DRYING OF GRAIN IN WINDROWS, SHOCKS, AND UNCUT

Previous to threshing the windrows, samples of grain for moisture content were taken at short intervals from the windrows, shocks, and uncut grain to determine the rate of drying of each. The first samples were taken immediately at windrowing time and continued every 2 hours thereafter from 9 A. M. until 7 P. M. This sampling was continued until pick-up combining was started.

It is evident from Figure 10 that the grain in the windrow will cure faster and be ready for combining at an earlier date than either shocked or uncut grain. The length of time required for grain in the windrow to cure depends upon weather conditions and the condition of the crop; if the windrow receives no rain, from two to three days will suffice; if rain is encountered, probably two additional days will be required before it will be ready for combining. In either case the green material (if any) should be thoroughly cured. The length of stubble on which the windrow rests and the size and nature of the windrow have a distinct influence on the curing process.

A windrow which is closely knit together with the heads of grain toward the center of the windrow and supported on medium length stubble, offers best protection from rain and dries out most rapidly.

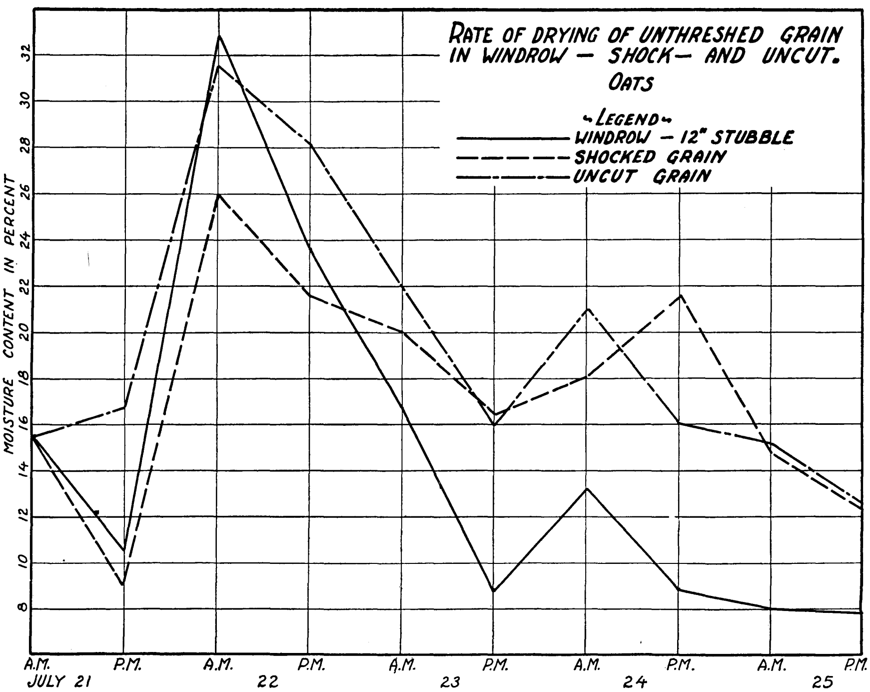
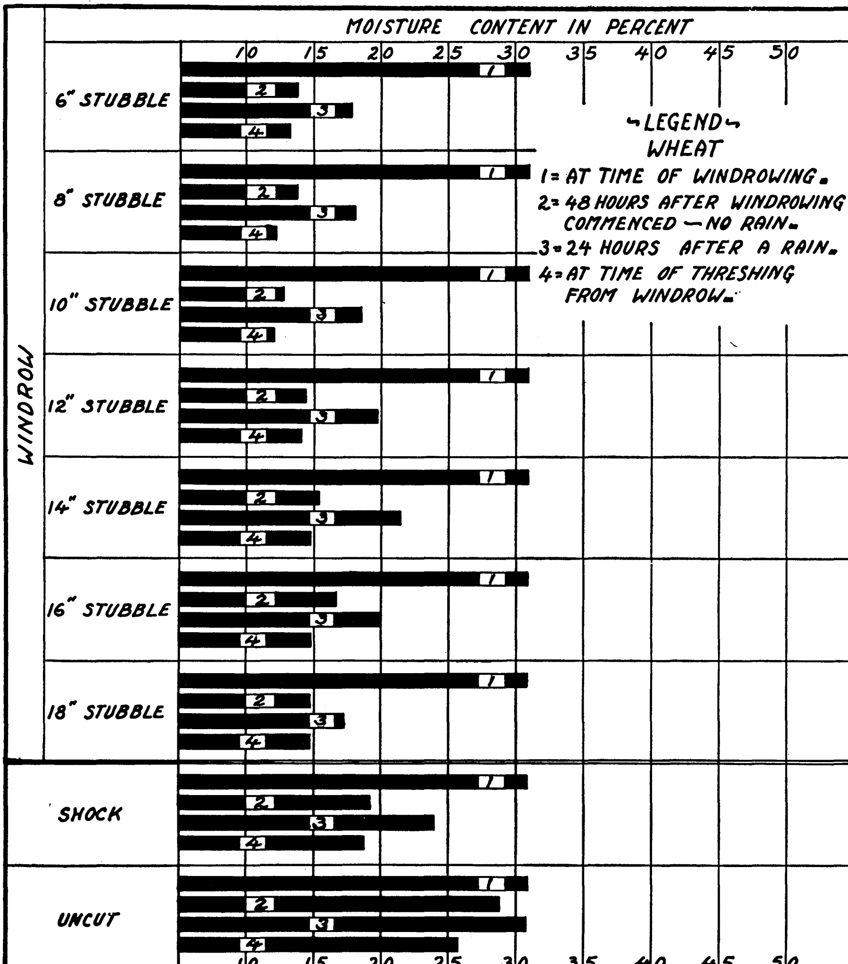


Fig. 10

It will be seen from Figures 11, 12, and 13 that after a rain a windrow on a 6-inch stubble will absorb less water than a windrow on a longer stubble. On the thin wheat crop, however, a slight decrease in moisture was noted from a 15-inch to an 18-inch stubble. The only explanation that can be given for this is that by observation on the 18-inch stubble the heads of grain were pointing directly toward the ground and therefore would probably be in a better position to shed the water. If no rain is encountered a windrow on a stubble of from 9 to 12 inches in length shows the most rapid rate of drying, preferably a 12-inch stubble on heavy



MOISTURE CONTENT OF UNTHRESHED GRAIN IN WINDROWS—SHOCKS—AND UNCUT UNDER VARIOUS WEATHER CONDITIONS.

Fig. 11

crops and a 9-inch stubble on light, thin crops. In practically every case, regardless of whether rain was encountered or not, a windrow on a stubble from 9 to 12 inches in length affords the greatest combination of drying facilities. At these heights of stubble the windrow is closely knit together so that water is readily shed and the stubble is of sufficient stability to support the windrow and yet afford excellent aeration underneath.

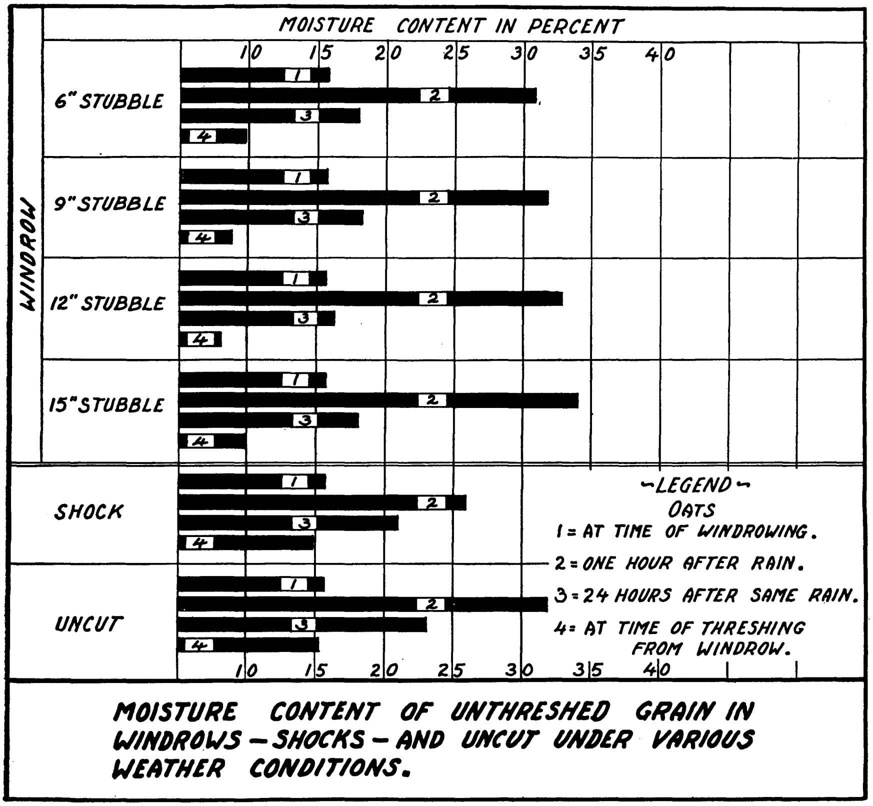


Fig. 12

If no rain is encountered, windrowed grain will dry out faster than either shocked or uncut grain, the uncut requiring longer time to be ready for combining. After a heavy rain the shock is the dryest, with the windrow and uncut grain about equal. As the drying period progresses, however, to approximately 24 or 30 hours

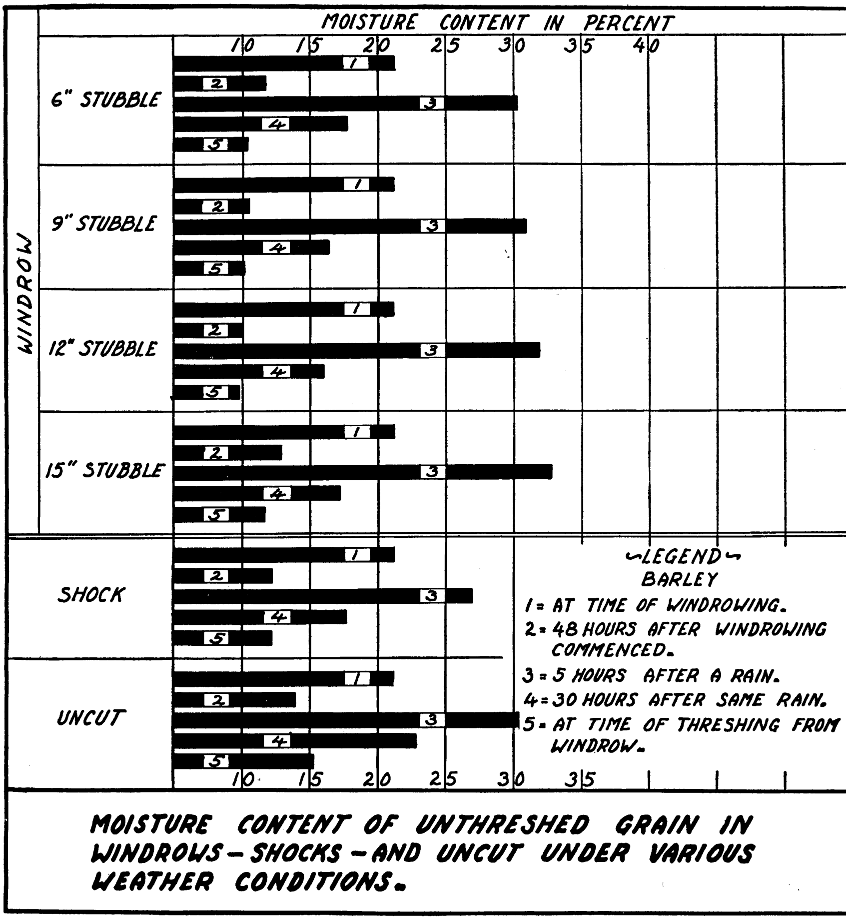

MOISTURE CONTENT IN PERCENT
10 15 20 25 30 35 40
WINDROW
6" STUBBLE
9" STUBBLE
12" STUBBLE
15" STUBBLE
SHOCK
UNCUT
1
2
3
4
5
LEGEND
BARLEY
1 = AT TIME OF WINDROWING.
2 = 48 HOURS AFTER WINDROWING COMMENCED.
3 = 5 HOURS AFTER A RAIN.
4 = 30 HOURS AFTER SAME RAIN.
5 = AT TIME OF THRESHING FROM WINDROW.
10 15 20 25 30 35
MOISTURE CONTENT OF UNTHRESHED GRAIN IN WINDROWS – SHOCKS – AND UNCUT UNDER VARIOUS WEATHER CONDITIONS.

Fig. 13

after a rain, the windrow is the dryest, followed in order by the shock and uncut. This is also true at the time of combining from the windrow. It is evident, therefore, that shocked grain will not be as wet after a rain as either windrowed or uncut grain. Windrowed grain, however, shows a more rapid rate of drying than that shown by either shocked or uncut grain. Shocked grain, once it is thoroughly wet, requires considerable time to dry because of inadequate air circulation throughout the shock. The uncut grain retains moisture for a considerable period after a rain, even if the crop is fully matured.

Fig. 14.—A medium height stubble supports the windrow properly and affords excellent aeration underneath.

SOYBEAN HARVESTING

A combine harvester is most satisfactory for harvesting soybeans. The amount of beans lost by the combine method of harvesting is much less than by any of the older methods. In most cases the windrow-pick-up method of harvesting this crop has not proved successful. The stubble is generally of such length that it will not support a windrow properly. The stubble is short and the windrow rests close to the ground. Poor air circulation is offered beneath the windrow and, if rains are experienced, the windrow is beaten to the ground where it becomes very dirty and the fingers on the pick-up device will not function properly. To combine successfully the crop should always be fully matured. Inasmuch as many soybeans shatter badly, a non-shattering variety should be grown.

To prevent crackage of beans, the cylinder speed must be reduced approximately 30 to 40 per cent. This is accomplished by placing a larger pulley or sprocket on the cylinder shaft or a smaller pulley on the engine. The remainder of the moving parts, however, such as the rack, shoe reel, etc., must be kept at the regular speeds. This is accomplished by changing pulleys or sprockets from the cylinder in similar manner. Inasmuch as soybeans crack easily, it is recommended that as few concaves be used as possible, and that the teeth be given more clearance than would ordinarily be employed on other crops. Two rows, or even one row, of teeth in the concaves, have been found to be sufficient to get the beans out of the pods. If the beans are very dry all the concaves may be removed and wooden blanks inserted. Beans, if harvested at the proper stage of maturity, are not hard to clean.

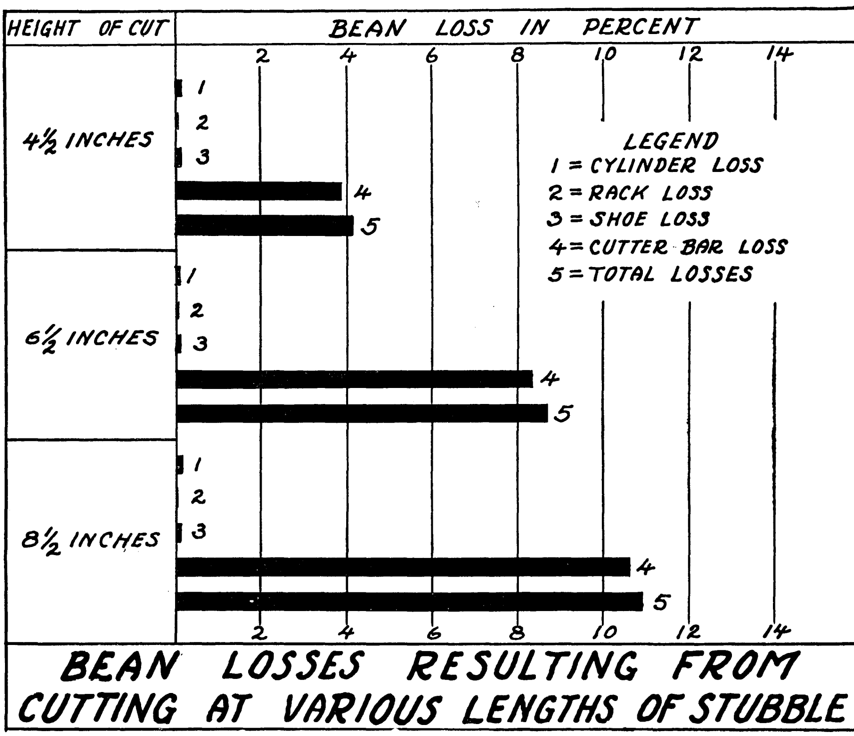


Fig. 15

The cutter-bar loss, Figure 15, is the greatest in harvesting soybeans with a combine. This loss, however, can be reduced greatly if the cutter bar is set close to the ground.

Very little difference is noted from the other losses due to the different heights of stubble. To reduce the cutter-bar loss further the reel should be set low and additional slats installed. Special types of cutter bars will also help to reduce the cutter-bar loss.

METHODS OF HANDLING THE STRAW

Since only a few of the combines in Ohio are owned by dairy farmers, there is not a great desire at the present time to save all the straw. However, this is an operation which should not be overlooked.

When straw is to be saved many farmers find it most convenient to have it baled; therefore, it should lay for a reasonable length of time, after combining, to cure. If the crop has been windrowed this will not be necessary. Several methods have been tried out, but only one at the present time seems to be practical. The straw spreader should be removed. The baler can be set in a convenient place in the field and relocated when necessary. By

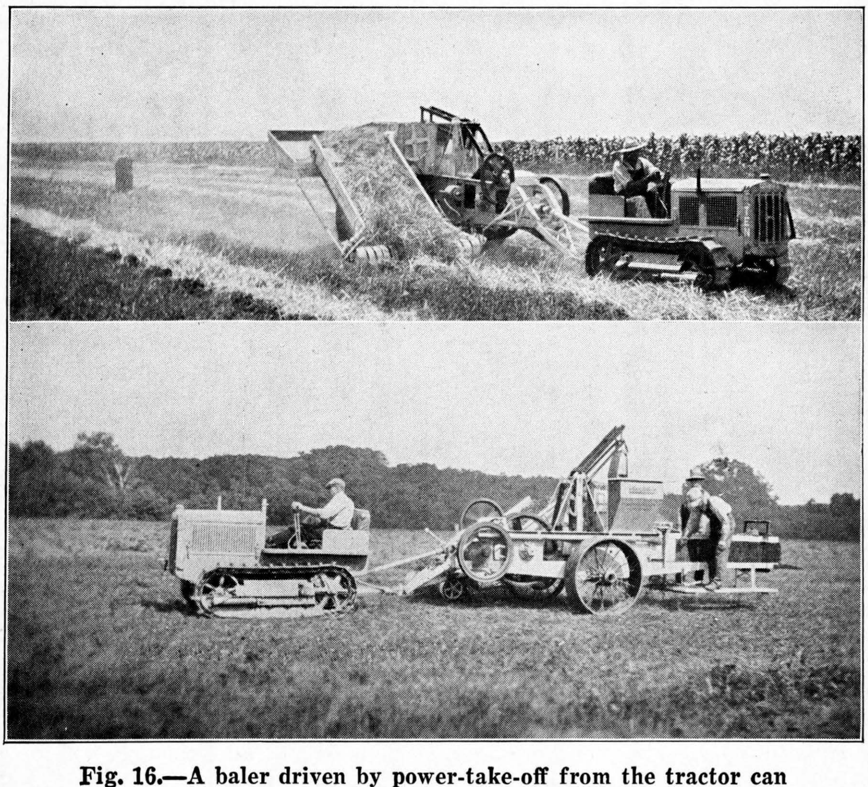


Fig. 16.—A baler driven by power-take-off from the tractor can be used to bale the straw in the field

Courtesy of Ann Arbor Machine Co.

means of a rake, preferably a buck rake, the straw can be collected and carried to the baler. The cost of operation is not much higher than baling from the stack as Table 15 will indicate.

TABLE 15.—Comparative Operating Costs Only of Baling Straw From the Field or Stack

Item	Rate	Field baling (Cost per ton)	Stack baling (Cost per ton)
		Dollars	*Dollars*
Man labor	35 cts. per hour	1.25	1.18
Gasoline	17 cts. per gallon	.21	.10
Oil	25 cts. per quart	.04	.01
Total		1.50	1.29

A buck-rake was used for this work. This was the type which was mounted on the tractor, requiring only one operator. A home-made buncher was used on the combine to place the straw in heavier windrows.

There are other methods employed to bale the straw which work with varying success. Some makes of balers are now equipped with a pick-up and elevating device to elevate the straw to the baler which is drawn over the field by a tractor.

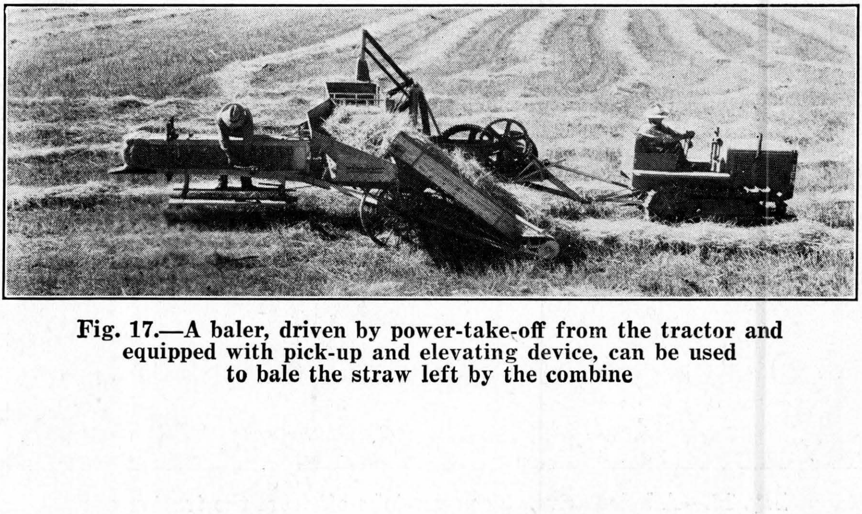


Fig. 17.—A baler, driven by power-take-off from the tractor and equipped with pick-up and elevating device, can be used to bale the straw left by the combine